

MINERAL ASSESSMENT REPORT

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Introduction

The aim of the regional assessment of minerals potential is to draw together new and existing information to aid the consideration of economic effects of forest use options to be considered in the development of the Regional Forest Agreement (RFA). In particular, this assessment contributes to the evaluation of:

- the nature of mineral resources in forested land;
- current and potential uses of forested land;
- economic value of mineral products;
- structure and regional significance of the mining industry; and
- resource, infrastructure and policy requirements for the establishment of minerals industries.

The National Forest Policy Statement recognises the need to consider access for mineral exploration and extraction activities in deciding on land use for public native forests. Access for mining and exploration varies with land tenure. Due to the incomplete nature of information on minerals resources and the fact that exploration is a dynamic information-gathering process, continued access to land is a significant issue for the mining industry and for future mineral development.

This report outlines: identified mineral deposits; the potential for a number of deposit types; indicators of the region's potential mineral value, and factors affecting this value. Mineral deposits outside but close to the boundary of the region (within 15 km) are noted if they are considered to have significance for mineral potential within the region. In this report the study area is referred to as 'the Gippsland region' or as 'the region'.

The major mining activity in the Gippsland region is the exploitation of brown coal resources which provide a major source of energy for electricity generation. Total brown coal reserves for the Gippsland Basin have been estimated at 96 300 million tonnes, while total resources have been calculated at over 172 874 million tonnes (Gloe & Holdgate 1991). Known brown coal resources are sufficient for well in excess of 60 years.

The region was a major gold producer last century, and many old deposits have recently attracted exploration interest. Resources have been identified at a number of prospects within the region or just adjacent to it.

The region is highly to moderately prospective for a number of mineral deposit types and is therefore likely to contain a number of undiscovered deposits.

Where access for exploration is possible, both undeveloped and as yet undiscovered deposits may be mined in the future subject to normal approval processes, and yield economic benefits.

The mineral resources assessment is based on data supplied by Minerals and Petroleum Victoria (MPV) and the latest geological reports. MPV reports used for the assessment include those on the 1:250 000 scale map sheet areas of Tallangatta, Warburton, Bairnsdale, Warragul, and Sale, the *Geology of Victoria* (edited by Douglas & Ferguson 1988). Reports

on specific geological areas within the region such as the Melbourne Zone (O'Shea *et al.* 1992) and the Mount Wellington area (VandenBerg *et al.* 1995). These reports describe the geology, mineralisation and exploration of the Gippsland region. Information on the industrial minerals in the Gippsland region is derived in part from a report by McHaffie and Buckley (1995), seminar publications and from other sources.

Only parts of the Gippsland region have been subjected to a detailed high resolution airborne geophysical surveys or to recent detailed (1:100 000 scale) geological mapping. Additional surveys are being planned by MPV and will generate new data which will lead to renewed mineral exploration and improved understanding of mineral deposition in the region.

Part 1

Known and potential resources of metalliferous and extractive minerals

Geological setting

The regional geological setting is shown on Map 1, and the main geological and mineralising events are summarised in Tables 1a and 1b. In the Gippsland region the Palaeozoic basement rocks in the northern part of the region are grouped into three structural zones. From west to east these zones are:

- Melbourne Zone
- Tabberabbera Zone
- Omeo Zone

The Mount Wellington Fault Zone marks the boundary between the thick Silurian-Devonian marine Melbourne ‘Trough’ sequence and the Tabberabbera Zone to the east. Discontinuous exposures of the underlying Cambrian greenstone basement rocks occur along the fault zone. The Kiewa Fault zone defines the eastern limit of the Tabberabbera Zone and separates it from the Omeo Metamorphic Complex to the east.

Volcanic rocks and associated granite plutons of Silurian and Devonian age form a large magmatic province. Volcanic cover rocks of Upper Devonian age occur within large calderas. These are overlain by sediments that are part of the Howitt Province, a broad north-west-trending graben that continues almost to the coast at Bairnsdale.

The Palaeozoic basement rocks are overlain by Cretaceous and Tertiary sediments of the *Gippsland Basin* in the southern portion of the region.

Melbourne and Tabberabbera Zones

The Palaeozoic rocks of the Melbourne and Tabberabbera Zones show a complex history of marine and subaerial sedimentation and volcanism interrupted by several major deformations and periods of granite intrusion. The final event was mild folding of molasse-type redbeds in the Carboniferous, after which there was prolonged erosion. Further erosion after the Permian resulted in a landscape of low relief by late Mesozoic times. The breakup of Gondwana in the Cretaceous caused uplift of several thousand metres to form the Eastern Highlands, which extend into the northern part of the region.

Cambrian volcanism and sedimentation (greenstones) (530–490 million years (Ma))

During the Cambrian period, basalt and andesite volcanic flows erupted on the sea floor over much of the area which is now Central Victoria. These flows alternated with episodes of quiet accumulation of pelagic shale, chert and deposition of volcanogenic sediments. This sequence of basic volcanics and sediments (referred to as ‘greenstones’) accumulated in an oceanic island arc geological setting and represent part of the Cambrian oceanic crust.

Table 1a Tabberabbera and Melbourne Zones—summary of geological and mineralising events

Geological Time Scale		Age (Ma)	Sedimentation and associated volcanics	Magmatism	Major geological events	Main mineralisation events	
PALAEOZOIC	Permian	251			Erosion of landscape		
	Carboniferous	298					
	Devonian	354			Kanimblan deformation		
				Mansfield Group Red beds	Caldera volcanism rhyolite, ignimbrite granitoid intrusions* Woods Point dyke swarm Granitoid Intrusion	Tabberabberan deformation Mount Wellington & Kancosna Fault Zone	'Red bed' sediment hosted copper uranium Tin veins Tin greisens Tungsten - moly veins Epithermal gold Copper - gold porphyry
	Silurian	410		Marine sedimentation Melbourne Trough mudstone, sandstone, minor conglomerate			
	Ordovician	434				Benambran deformation	
Precambrian	Ordovician	490	Deep marine sedimentation sandstone* mudstone* (*turbidity current deposits) black shale, chert, siltstone				
	Cambrian	545	'Greenstones' mafic volcanics chert volcaniclastics			Epithermal gold Chromite Copper in basic volcanics Volcanic massive sulphide	
TABBERABBERA AND MELBOURNE ZONES							

Ma) Million years ago

Table 1b Omeo Zone and Gippsland Basin—summary of geological and mineralising events

Geological Time Scale		Age (Ma)	Sedimentation and associated volcanics	Magmatism	Major geological events	Main mineralisation events
PALAEOZOIC	Quaternary	1.78	Recent stream deposits			Placer gold
	Tertiary	65	Shallow water non-marine basin, swamps. Sandstone, mudstone, greywacke, brown coal	Older basalt	Basin subsidence, rift faulting, Latrobe Valley Depression	Brown coal (very thick seams), placer gold, heavy mineral sands
	Cretaceous		Sandstone (Strzelecki Group)			Sandstone hosted uranium, black coal (thin seams)
	Jurassic			Mount Lenister Complex volcanics, andesite	Erosion of land surface	
	Triassic	251				
	Permian	298				
	Lower Carboniferous	354	Avon River Gp, Mt Tambo Gp: conglom, sst, red mudstone	Wellington rhyolite	Kanimblan deformation	Vein gold, silver
	Upper Devonian			Tabberabbera dyke swarm Granite intrusion		'Red bed' sediment hosted copper uranium
	Lower Devonian		Shallow marine shelf limestone Silicic volcanism (Snowy River Vole & Mt Elizabeth Caldera Vole's)	Granitoids of Mount Elizabeth & Snowy River volcanics	Tabberabbera deformation Buchan Rift	Granite related tin, tungsten, gold
	Upper Silurian	410	Graben filled with felsic volcanics, marine sedimentation limestone	Felsic volcanics Granite intrusion	Bindian deformation Limestone/Wombat Ck Grabens	Carbonate hosted base metal Nova Nova Ironstone Epithermal gold, silver Porphyry copper Granite-related gold Vein gold, silver
GIPPSLAND BASIN	Lower Silurian	434	Deep marine sedimentation sandstone, siltstone		Quidongian deformation, metamorphism	VMS base metal (Benambra) Porphyry copper, Vein gold, silver
	Ordovician	490	Deep marine sedimentation sandstone* mudstone* black shale, chert, siltstone*/turbidity current deposits)		Benambra deformation	

(Ma) Million years ago

Styles of mineralisation associated with these Cambrian greenstones include:

- epithermal gold mineralisation, e.g. Rhyolite Creek, Great Rand mine,
- small chromite deposits formed during crystallisation of ultramafic rocks,
- copper mineralisation associated with Cambrian volcanics,
- manganese and iron deposits (exhalative deposits) formed during hydrothermal exhalations in sedimentary environments on the ancient sea floor.

Ordovician deep marine sedimentation (490–430 Ma)

At about the Cambro-Ordovician time boundary, a large submarine fan of sediments encroached into the region from the west, extending across most of Victoria and south-eastern New South Wales. In the region, these rocks are represented by the Hotham Group which consist of sandstones and mudstones deposited by turbidity currents into the deep marine environment along the eastern margin of the Australian Craton. Thin chert beds were deposited in areas where turbidity currents were less common.

In the Late Ordovician, the region continued to be in a deep marine environment, and the main deposition was quiet accumulation of silt, mud and marine organisms on a deep anoxic seafloor. In the Tabberabbera Zone, the sediments are mainly black siliceous shales containing abundant graptolites. In the Melbourne Zone, a similar black shale sequence (Mount Easton Shale) was deposited during the same period.

Early Silurian Benambran Deformation (430–425 Ma)

The Benambran Deformation was the main episode of folding and metamorphism in much of eastern Victoria, including the Tabberabbera and Omeo zones, however the Melbourne Zone rocks were unaffected. During this event, the Ordovician rocks were tightly folded. High heat flow and upwelling of granite magma altered the deeply buried sediments in the east during low pressure metamorphism (Omeo Metamorphic Complex). Granite magma slowly moved towards the surface and began to metamorphose local country rock. In some places, the heat was sufficient to begin melting the sedimentary rocks, forming migmatites.

Early Silurian to Early Devonian marine sedimentation (430–385 Ma): Melbourne 'Trough'

Deep marine sedimentation continued from the Late Ordovician through the Silurian into the late Early Devonian without interruption in the Melbourne 'Trough'. The Silurian and lower part of the Lower Devonian sequence consists of slowly deposited mudstone and fine-grained quartzose sandstone, known as the Jordan River Group. This is overlain by the Walhalla Group, which is a thick sequence of well-bedded sandstone turbidites and mudstone, and minor conglomerate.

Middle Devonian Tabberabberan Deformation (385–380 Ma)

In the Middle Devonian, the second major compressional deformation to affect the Gippsland region, folded and faulted the rocks of the Melbourne Zone. The Mount Wellington Fault Zone formed at this time. Slate belt type gold (with minor antimony) deposits were formed in structures related to the Tabberabberan deformation. The types of slate belt gold deposits which can be recognised in the region include: sediment-hosted; granitoid related; and dyke affiliated.

Middle to Late Devonian caldera volcanism (375–365 Ma): Wabonga caldera

The Wabonga caldera began with deposition, in the late Middle Devonian, of fluvial conglomerates followed by the first collapse phase, with explosive eruption of ignimbrites (Hollands Creek Ignimbrite). This first phase was followed by block faulting and erosion prior to eruption of several thick ignimbrite sequences. Further block faulting and erosion took place prior to the main phase of Late Devonian fluvial sedimentation of the Mansfield Group which overlie the caldera volcanics.

During this period there were a number of granitoid intrusions, many of which were co-magmatic with caldera volcanics. The age of these intrusions cluster around 365 Ma (O'Shea *et al.* 1992).

A period of gold mineralisation within the Gippsland region took place during late to post-tectonic movements associated with these intrusions (O'Shea *et al.* 1992). Gold deposits occur both in the granitoids and the adjacent deformed sediments. Gold mineralisation also occurs in breccia pipes and stockworks within granitoids and volcanics.

Tin, tungsten, molybdenum and bismuth occur as vein mineralisation associated with granitoid intrusions (Ramsay & VandenBerg 1986).

Late Devonian 'red-bed' style sedimentation (370–355 Ma): Mansfield Group

In the Late Devonian, a large river system deposited flood-plain sediments across much of the region. The sequence is broadly upward fining from conglomerate and sandstone in the basal Mount Kent Conglomerate, to predominantly red mudstones of the Snowy Plains Formation. Sedimentary 'red-bed type' copper mineralisation occurs within sandstone and shale (Ramsay & VandenBerg 1986). Anomalous concentrations of uranium are also present in these redbeds.

Early Carboniferous Kanimblan Deformation (350 Ma?)

Deformation mainly associated with large faults and shear zones occurred during the Kanimblan Deformation. The late Devonian 'red-beds' are faulted and deformed in places.

Late Cretaceous break-up of Gondwana (ca 95–65 Ma)

The geological history of the region during the last 100 million years was controlled by the break-up of the Gondwana supercontinent, especially the separation of Australia from Antarctica and New Zealand. This began in the Mid-Cretaceous about 95 million years ago, when the Tasman Sea began to open, and major subsidence occurred in the Gippsland and Otway Basins. This was combined with major uplift of a broad belt to the north of the coastal plain, forming the Great Dividing Range.

Late Cretaceous to Recent stream incision, basaltic volcanism, block faulting, fluvial sedimentation (80? Ma-Recent)

The Late Cretaceous uplift began a cycle of incision and lateral erosion by streams that continues at the present day. There were localised interruptions to this erosion cycle by eruption of basalts. In the late Eocene and Oligocene, basalts of the Older Volcanics were erupted.

Omeo Zone

(Summarised from information presented in Maher *et al.* 1996).

Ordovician deep marine sedimentation (500–438 Ma)

Deposition of sediments in a deep marine environment commenced in the Early Ordovician (500 Ma). These extended over much of Eastern Victoria and include the Hotham Group, Pinnak Sandstone and Broadbent River Sandstone. Sandstones and mudstones were deposited by turbidity currents into the deep marine environment. The nature of the sedimentation changed, and by the Late Ordovician silts and mudstones were deposited by quiet sedimentation on the sea floor in a deep-water environment. The Blueys Creek Formation was also deposited in a similar environment and it contains turbidites that were derived from mafic igneous rocks. The Hotham Group forms the basement and host to most of the post Ordovician igneous and volcanic complexes and graben structures.

Early Silurian Benambran deformation (ca 440 Ma)

In the Early Silurian, the Benambran deformation resulted in deformation and metamorphism of the northern portion of the Omeo Zone (north of Gippsland region), however this deformation appears to have had little effect in the area of the Gippsland region.

Early Silurian (440–430): Seldom Seen Formation, Towong Sandstone, Yalmy Group, Cobbannah Group

Deep water sedimentation continued into the Early Silurian with deposition of the Seldom Seen Formation, Towong Sandstone, Yalmy Group and Cobbannah Group. These sediments are mainly sandstones and siltstones.

Middle Silurian Quidongan Deformation

The main phase of folding and deformation in the Omeo zone was during the Middle Silurian. It resulted in folding and metamorphism of the Ordovician and Lower Silurian rocks, and was accompanied by intrusion of I and S type granites.

Middle to Late Silurian (425–410 Ma): Limestone Creek Graben, Wombat Creek Graben

The Limestone Creek and Wombat Creek grabens were formed by rift faulting in the Middle Silurian (Bolger *et al.* 1983). These grabens were filled with interbedded successions of felsic volcanics and marine sediments including limestone. The Wilga and Currawong base metal deposits are associated with these volcanics.

Late Silurian Bindian Deformation (410 Ma)

This deformation occurred at the end of the Silurian. The volcanics and sediments of the Limestone/Wombat Creek grabens were folded for the first time. Major faults, which formed during this deformation, include the Kiewa, Ensay and Indi faults. Vein gold deposits are associated with this deformation.

Early Devonian rifting and volcanism (410–395 Ma): Buchan Rift, Mount Elizabeth Caldera Complex

Following the Bindian deformation, a major graben structure began to develop in eastern Victoria, when crustal thinning gave rise to a deep and broad basin known as the Buchan Rift (Orth *et al.* 1995). After the initial deposition of conglomerates, a minor phase of intermediate volcanism, followed by voluminous subaerial silicic volcanism formed the Snowy River Volcanics (Orth *et al.* 1995). The whole rift fill sequence is considered to be Early Devonian in age.

The Mount Elizabeth Caldera Complex also formed during the Early Devonian. A thick sequence of shallow marine clastic sediments and limestone were deposited in a sedimentary basin to the west of the Buchan Rift. Porphyry copper style mineralisation is associated with these intrusions.

Early to Middle Devonian carbonate deposition (395–385 Ma): Buchan Group

During the Early Devonian, there was a rise in sea level and the region became a shallow marine shelf, on which limestones were deposited (Buchan Caves Limestone). These limestones were derived largely from the shells of organisms. The Nowa Nowa ironstones (skarns) are associated with these limestones.

Middle Devonian (385–380 Ma): Tabberabberan Deformation

The Tabberabberan deformation resulted in folding and faulting of the rocks of the Omeo Zone (including the Buchan Group).

Late Devonian to Early Carboniferous (380–355 Ma): Mount Hewitt Sedimentary Province, Avon River Group, Mount Tambo Group

During this period, volcanic and sedimentary sequences were deposited over deformed older rocks. The Avon River Group consists of conglomerates, sandstones and red mudstones. Redbed sediment hosted copper and uranium mineralisation is associated with these sediments.

Early Carboniferous to Mid-Cretaceous (ca 355–100 Ma)

Erosion of the land surface through this period produced a land surface of low relief. During the Triassic, the Mount Leinster Complex formed. Trachytic lavas and volcanoclastics were intruded by syenite and granite porphyry.

The Kanimblan Deformation took place during Early Carboniferous at about 335 Ma.

Mid-Cretaceous to present

In the late Cretaceous, the breakup of Gondwana commenced (ca 95–65 Ma). From the Palaeocene onward (65 Ma onwards) there was widespread erosion of the area by streams.

Gippsland Basin

Early Cretaceous (141 – 98 Ma): Strzelecki Group

The Gippsland Basin first developed as a rift basin in Lower Cretaceous times. Strzelecki Group sediments, which are the basal sediments of the Gippsland Basin, were deposited in a large shallow water non-marine basin. The basin contained extensive flood plains with braided streams and a variety of sedimentary environments including fluvial, lacustrine and deltaic (Douglas 1988). The main lithologies of the Strzelecki Group are feldspathic sandstone (arkose), mudstone, greywacke, conglomerate, carbonaceous layers and minor black coal units.

The basal sandstones of the Strzelecki Group unconformably overlie deformed Palaeozoic sediments, and are suitable host rocks for the formation of sandstone-type uranium deposits. Carbonaceous plant material (including thin coal beds) within these sands provide the reducing environment necessary for uranium precipitation.

Sedimentation ceased in the Middle Cretaceous during a period of uplift.

Tertiary (55 to 1.78 Ma)

Renewed rifting activities resulted in the recommencement of subsidence in the late Cretaceous with the deposition of sands, clays and brown coal seams over most of the Gippsland Basin. By Mid-Eocene the swamps in which the coal seams intermittently developed had extended over much of the on-shore area of the Gippsland Basin. During the time up to Late Miocene, very thick brown coal seams of the Traralgon, Morwell and Yallourn Formations accumulated in slowly subsiding shallow water basins (Gloe & Holdgate 1991, Gloe *et al.* 1988). These thick seams of brown coal are the basis for large-scale open cut mining operations in the Yallourn – Morwell area.

History of mining and known mineral and extractive resources

Map 2 shows 1057 mineral occurrences, old mines and deposits in the Gippsland region. Most of the 813 gold occurrences occur within 29 goldfields. Major resources of brown coal within the region form the basis of the Victorian electricity power industry. During the period 1923–1995, brown coal production has exceeded 1.1 billion tonnes. Known coal resources are sufficient to support current rates of production for well over 60 years.

Exploration and mining has historically focused on gold, then coal, oil and more recently base metals. Historical production of antimony, tin, tungsten and related minerals has been recorded. Of the 34 current mineral licences for gold (10 more are under application or renewal), none produced more than one kilogram of gold in 1996–97 (pers comm R Buckley, Geological Survey of Victoria 1998).

Mines within the Bairnsdale 1:250 000 scale map area (covering much of the northern part of the region) have intermittently produced in excess of 13.7 tonnes of gold, 45 000 tonnes of copper, 21 000 tonnes of zinc, 15 tonnes of silver and unknown quantities of lead, iron and other metals. The Bairnsdale area includes several of Victoria's most important mineral deposits, including Wilga and Currawong, the State's largest base metal deposits (Maher 1996). Sales of non-metallic minerals produced within the Bairnsdale 1:250 000 scale map area have exceeded \$2 million per annum.

Metals

Gold

Victoria's total gold production until 1988 was approximately 2 450 tonnes of gold (Ramsay & Willman 1988), of which 60 per cent was alluvial and 40 per cent from primary (hard rock) source (Ramsay 1995). Since its discovery in 1851, in excess of 13.7 tonnes of gold have been mined within the Bairnsdale 1:250 000 scale map sheet area, with about 33 per cent from alluvial and 67 per cent from primary sources respectively (Maher *et al.* 1996). Recorded historical production for the numerous alluvial and primary gold mines and occurrences is shown in Table 2. Systematic recording of production from alluvial placer deposits did not start until 1886 so reported production is probably significantly understated (Maher *et al.* 1996).

Known gold resources remaining within the region amount to 520 000 tonnes at 4.1 grams per tonne at Cohens Reef and 64 000 tonnes at 3.4 grams per tonne at Cassilis in tailings (Table 3).

Alluvial gold in the region was first discovered at Livingstone Creek, near Omeo in 1851 (Fairweather 1983, cited in Maher *et al.* 1996) and then found at Swifts Creek in 1854. Although known alluvial deposits within the Omeo, Swifts Creek and New Rush Creek goldfields were almost exhausted by 1879 (Howitt 1886, cited in Maher *et al.* 1996), hard rock and some alluvial gold mining continued in these goldfields into the early 1900s. Dredging on Livingstone Creek began at this time and continued on Swifts Creek until the early 1920s (Fairweather 1975, cited in Maher *et al.* 1996). The most important alluvial production (largely by hydraulic sluicing) in the Omeo goldfield was from the Oriental Claims.

Table 2 Recorded past gold production from goldfields, tinfields and gold deposits of the Gippsland region

Map 2 goldfield no./min. occur. locn	Goldfield Mine/prospect	Ore (tonnes)	Grade (g/t)	Gold (kg)	Period	Other source
G1	Indi River^a					
G2	Gibbo River^b					
	Alluvial			0.5	1904	Oppy et al. (1995)
	Primary	314	13.3	4.2	1889	Oppy et al. (1995)
G3	Buckwong Creek and Dinner					
G4	Mt Wills^b					
	Alluvial			30.0	1900–1950	Oppy et al. (1995)
	Primary	318 445	24.6	7 840.8	1892–1968	Oppy et al. (1995)
G5	Dead Horse Creek/Limestone Creek					
G6	Cobungra River^a	-	-	-	-	-
G7	Crooked River/Grant/High Plains					
	Dargo High Plains Goldfield					
	Alluvial incl:			65.0		Maher et al. (1996)
	Whites Claim			64.0		Maher et al. (1996)
	Primary incl:			204.0		Maher et al. (1996)
68	Evening Star		91	23.0		Maher et al. (1996)
	Hope Reef		57	55.0		Maher et al. (1996)
	Grant Goldfield					
	Alluvial			-		Maher et al. (1996)
	Crooked River Dredging			71.0		Maher et al. (1996)
	Primary incl:			702.0		Maher et al. (1996)
104	Good Hope		43	540.0		Maher et al. (1996)
293	Mountaineer Reef		24	32.0		Maher et al. (1996)
	Unlocated					
	Alluvial			226.0		Maher et al. (1996)
	Primary			417.0		Maher et al. (1996)
G8	Cassilis Goldfield/Omeo Goldfield/Swifts Creek					
	Omeo Goldfield					
	Alluvial incl:			-		Maher et al. (1996)
	Hinnomungie Dredging			1 031.0		Maher et al. (1996)
	Harrington Dredging			345.0		Maher et al. (1996)
	Oriental Claims	0.41/m ³		1 302.0		Millin (1983, cited in Maher et al. 1996)
	Primary incl:			886.0		Maher et al. (1996)
	Samaritan	53		21.0		Maher et al. (1996)
	Surprise Reef	104		20.0		Maher et al. (1996)
	Swifts Creek Goldfield (incl New Rush Creek Goldfield)					
	Alluvial incl:			1 769.0		Maher et al. (1996)
98	Tongio Gold Dredging			332.0		Maher et al. (1996)
	Omeo Gold Dredging			10.0		Maher et al. (1996)
	Primary incl:			4 203.0		Maher et al. (1996)
97	Cassilis	30		2 188.0		Maher et al. (1996)
121	Perseverance	10		131.0		Maher et al. (1996)
	Warden	69		119.0		Maher et al. (1996)
	King Cassilis	16		88.0		Maher et al. (1996)
	Grassmere	107		54.0		Maher et al. (1996)
G9	Black River					
	Wye's Creek Reef	9 to 620		na	1866 – ?	O'Shea et al. (1992)
	Standard Reef	na		na	"	O'Shea et al. (1992)
	New Standard Reef	na		na	"	O'Shea et al. (1992)
	Golden Fleece Reef	na		na	"	O'Shea et al. (1992)
	Weber's Reef	-		na	"	O'Shea et al. (1992)
G10	Woods Point/Walhalla Gold Sub Province^c					
	Gaffney's Creek Goldfield incl:					
269	A1 Mine		25	15 552.0	1857–1992	Noble Resources NL (1994)
			26	13 000.0	since 1863	O'Shea et al. (1992)
						grade: Bowen (1974)
69	Rose of Denmark Mine		12	1 831.0		O'Shea et al. (1992)
	Woods Point Goldfield incl:		31	31 103.0	na	Alcaston Mining NL (1994)
268	Morning Star Mine		24.5	27 371.0	na	Mt Conqueror Minerals (1994)
					na	Fethers G (1996)
	BB Quartz Mine		26.4	55.0	na	O'Shea et al. (1992)
	United Gleasons Mine		na	880.0	na	O'Shea et al. (1992)
	Matlock Goldfield incl:					
	Loch Fyne Mine		24	3 419.0	na	O'Shea et al. (1992)
	All Nations Mine		na	4 105.0	na	O'Shea et al. (1992)
	Donnelly's Creek Goldfield incl:					
	Toombon Mine		23	1 384.0	1872–97	O'Shea et al. (1992)
	Donnelly's Creek Reefs incl:		na	809.0	1863–1909	Alcaston Mining NL (1994)
	Bismark Mine		48	357.0	na	Alcaston Mining NL (1994)
	Edwards Hill Mine		22	183.0	na	Alcaston Mining NL (1994)
	Walhalla-Aberfeldy Goldfield incl:					
182	Cohens Reef	1 400 000	33	46.6	1863–1914	O'Shea et al. (1992)

Map 2 goldfield no./min. occur. locn	Goldfield Mine/prospect	Ore (tonnes)	Grade (g/t)	Gold (kg)	Period	Other source
G11	Bulumwaal/Dargo River/Mitchell River/Nicholson River/Wentworth River					
	Bulumwaal Goldfield					
	Alluvial			15.0		Maher et al. (1996)
	Bulumwaal Gold Dredging			15.0		Maher et al. (1996)
	Primary incl:			656.0		Maher et al. (1996)
144	Beehive Mine	17		331.0		Maher et al. (1996)
	Sons of Freedom Reef	19		94.0		Maher et al. (1996)
	Christmas	17		54.0		Maher et al. (1996)
	Defiance	76		48.0		Maher et al. (1996)
	Deptford Goldfield					
	Alluvial			-		Maher et al. (1996)
	Primary incl:			80.0		Maher et al. (1996)
	Deptford Proprietary Mine		49	34.0		Maher et al. (1996)
	Success Reef		31	25.0		Maher et al. (1996)
	Dargo Goldfield					
	Alluvial incl:			220.0		Maher et al. (1996)
	Dargo Gold Dredging			22.0		Maher et al. (1996)
	Primary incl:			177.0		Maher et al. (1996)
145	Exhibition		31	59.0		Maher et al. (1996)
121	Perseverance		27	46.0		Maher et al. (1996)
124	Little Exhibition		20	-		Maher et al. (1996)
	Store Creek Goldfield					
	Alluvial			-		Maher et al. (1996)
	Primary incl:			18.0		Maher et al. (1996)
	Tambo Reef		10	16.0		Maher et al. (1996)
	Aunum Mine		19	1.0		Maher et al. (1996)
	Yahoo Goldfield					
	Alluvial			-		Maher et al. (1996)
	Primary incl:			9.0		Maher et al. (1996)
	Great Scott Mine		18	5.0		Maher et al. (1996)
	Gift Mine		90	2.0		Maher et al. (1996)
	Unlocated					
	Alluvial			2 144.0		Maher et al. (1996)
	Primary			680.0		Maher et al. (1996)
G12	Haunted Stream					
	Haunted Stream & Shady Creek					
	Goldfields					
	Alluvial			78.0		Maher et al. (1996)
	Primary incl:			1 026.0		Maher et al. (1996)
	Rob Roy		31	55.0		Maher et al. (1996)
128	Hans		11	52.0		Maher et al. (1996)
G13	Cobbannah Creek					
	Alluvial			-		Maher et al. (1996)
	Primary incl:			24.0		Maher et al. (1996)
139	Budgee Budgee Reef		24	24.0		
143	Whitehorse Reef		7	1.0		
G14	Lees Creek					
G15	Gladstone Creek			not reported		Maher et al. (1996)
G16	Turtons Creek					
G17	Foster Goldfield					
G18	Waratah Bay					
G19	Crossover-Neerim^d					
	Alluvial	na	na	na	1864 – ?	O'Shea et al. (1992)
	Primary					
	Albian Reef	na	na	na	1864 – ?	O'Shea et al. (1992)
	Happy Go Lucky Reef	na	na	na	1864 – ?	O'Shea et al. (1992)
G20	Tanjil (Russells Creek)^d					
	Alluvial		na	>50kg	1859 – ?	Murray (1880, 1916: cited in O'Shea et al. 1992)
	Primary		3 to 90	na	1859 – ?	O'Shea et al. (1992)
G21	Tyers River^d					
	Alluvial	na	na	na	1859 – ?	O'Shea et al. (1992)
G22	Howqua Goldfield & Howqua River Chromium Field^d					
276	Great Rand & Howqua United mines	300–1 000	Up to 30		1863–late 1880s	Transkal Gold NL (1994)
G23	Buckland River^a	-	-	-	-	-
G24	Bright-Wandiligong-Freeburgh-Harrietville^e					
	Alluvial			8 537.2	1883–1955	Oppy et al. (1995)
	Primary	528 634	21.7	11 452.3	1861–1993	Oppy et al. (1995)
G25	Jarvis Creek^f					
	Primary	418	17.4	7.2	1877–1907	Oppy et al. (1995)
G26	Big River^f	-	-	-	-	-
G27	Mitta Mitta^f					
	Alluvial			993.0	1889–1915	Oppy et al. (1995)
	Primary	33 519	50.9	1 702.6	1876–1950	Oppy et al. (1995)

Map 2 goldfield no./min. occur. locn	Goldfield Mine/prospect	Ore (tonnes)	Grade (g/t)	Gold (kg)	Period	Other source
G28	Dart River – Zulu Creek ^f Alluvial Primary	10 470	54.3	48.9 568.7	1881–1905	Oppy et al. (1995) Oppy et al. (1995)
G29	Tara Goldfield ^g Alluvial Primary incl: Monarch of Tara Micawber			- 38.0 5.0 1.0		Maher et al. (1996) Maher et al. (1996) Maher et al. (1996) Maher et al. (1996)
-	Miscellaneous					
42	Angler's Rest Field: Leviathan Reef	505	15.3	7.7	1903	Oppy et al. (1995)

- a. Partly within Gippsland
b. Small part within Gippsland
c. Just west and partly within Gippsland
d. Just west of Gippsland
e. Just outside Gippsland
f. Just north of Gippsland
g. Just east of Gippsland

Table 3 Resources in gold deposits of the Gippsland region

Map2 goldfield locn/min. occur. locn	Goldfield Mine/prospect	Material (tonnes)	Grade (g/t)	Gold (kg)	As at	Source
G4	Mount Wills ^a Glen Wills-Sunnyside (United Brothers mine to Maude & Yellow Girl mine) ^b Indicated Inferred Tailings/Dumps Measured Indicated	16 000 140 000 113 000 107 000	9.8 12.7 2.6 5.3	157 1 778 294 567	30/6/1997 30/6/1997 30/6/1997 30/6/1997	Austr. Goldfields NL (1997) Austr. Goldfields NL (1997) Austr. Goldfields NL (1997) Austr. Goldfields NL (1997)
G8 97	Cassilis/Omeo/Swifts Creek Cassilis Tailings	64 000	3.4	217.6	30/6/97	Austr. Goldfields NL (1997)
G10 268	Woods Point/Walhalla Gold Sub Province ^c Morning Star mine ^d Surface (o/cut) Underground Below Level 2	464 000 1 577 000	2.6 5.5	1 206 8 674	30/6/1998 30/6/1998	Mt Conqueror Minerals (1998) Mt Conqueror Minerals (1998)
269	A1 Mine ^d Inferred Inferred Inferred 'Pre-resource' Jamieson-Woods Point-Aberfeldy Gold Centre ^d Indicated	25 000 414 000 150 000 60 000 300 000	15.3 4.3 na na 9.50	383 1 780 na na 2 850	1993 1993 1993 1993 1987	Broken Hill Holdings (1993) Broken Hill Holdings (1993) Broken Hill Holdings (1993) Broken Hill Holdings (1993) MINMET (1998)
182	Cohens Reef Resource	520 000	4.1	2 132	1994	Intrepid Mining Corp (1994)
G22 276	Howqua ^d Great Rand mine	215 000	6	1 290	24/6/1994	Transkal Gold NL (1994)
G24 280	Bright-Wandiligong ^e Sambas mine ^b Proved	10 000	30	300	9/8/1989	MINMET (1998)

- a. Small part within Gippsland
b. Just outside Gippsland
c. Just west and partly within Gippsland
d. Just to west of Gippsland
e. Partly within Gippsland

Gold was discovered at Cobungra River in the Dargo High Plains goldfield in 1852 and alluvial mining commenced in 1857 while mining of gold bearing leads buried by Tertiary age basalt commenced in 1867. The main period of mining on Cobungra River started in 1884, and coincided with the introduction of hydraulic sluicing on Brandy and Murphys Creeks. Sluicing operations ceased in 1894 (Maher *et al.* 1996).

Alluvial mining was reported on the Dargo River at Pikes Creek from 1854 and a government prospecting party discovered alluvial gold at Crooked River in 1860 (Bannear & Annear

1995, cited in Maher *et al.* 1996). In the Bulumwaal-Deptford-Store Creek-Yahoo goldfields, significant placer gold deposits occurred in and adjacent to the Nicholson River, the Prospect (Boggy) Creek, Yahoo Creek, Store Creek and Clifton Creek. These deposits produced significant amounts of gold prior to the 1900s (Maher *et al.* 1996).

Historical primary (hard rock) gold production was from numerous small mines located on quartz veins, reefs or stockworks in faults or fissures. A wide range of mining methods were used to extract the primary ore, including surface workings, shallow open pits, shafts, adits, winzes and drives. Ore grades were high, at 22 to 30 grams per tonne gold or more.

The Woods Point-Walhalla gold sub-province, extending into the western edge of the region, was a major gold producing zone with historical hard rock gold production amounting to over 99 tonnes since 1860.

Gold in the Harrietteville-Dargo province (west of the Kiewa Fault) occurs in low sulphide quartz veins and is largely non-refractory (not bound up in other minerals). In the Dargo High Plains goldfield, the Evening Star mine was the largest producer with an average grade of 23 grams per tonne gold, while the Hope and Homeward Bound mines averaged 55 grams per tonne at and 258 grams per tonne respectively ('G7', Map 2). Despite these grades, mines were commonly abandoned at relatively shallow depths. In the Deptford goldfield, gold bearing vein sets can be mineralised over kilometres of length, such as at the New Enterprise mine the veins were selectively mined to depths of up to 150 metres. In the Grant goldfield, the Good Hope mine was the largest producer and was mined to a depth of 263 metres, at an average grade of over 43 grams per tonne gold. Further east in the Haunted Stream goldfield, gold grades were relatively low but the veins were relatively wide and in soft easily worked host rock (Fairweather 1975, cited in Maher *et al.* 1996). Mineralisation also extended into the host sediments.

Gold bearing quartz veins in the Benambra province (east of the Kiewa Fault), particularly in the Omeo Metamorphic Complex, typically have high sulphide and base metal values (Ramsay & Willman 1988). Gold was mainly refractory (contained within sulphide or other minerals), which often interfered with its recovery.

In 1858, a gold bearing quartz vein was discovered at Cassilis, in the New Rush goldfield, and it was reported (Christie 1993, cited in Maher *et al.* 1996) as the first hard rock gold discovered in Gippsland. Cassilis was the largest gold producer in the Bairnsdale area where steeply dipping quartz-gold-sulphide veins were worked extensively on twelve underground levels (MacLennan 1987, cited in Maher *et al.* 1996). Ore was highly refractory and contained base metal/antimony sulphides.

In the Omeo, Swifts Creek and New Rush Creek goldfields, primary gold was associated with unusually high levels of iron, arsenic, copper, lead and zinc sulphide minerals (Rosales 1897, cited in Maher *et al.* 1996). This led to the abandonment of many mines once the free gold in the upper, oxidised zone had been extracted. In the early 1900s, several plants designed to recover gold from sulphide were introduced to the goldfields (Fairweather 1975, cited in Maher *et al.* 1996) which facilitated a boom in mine production.

High grade silver commonly occurred in auriferous quartz veins hosted by granitic gneiss and mica schist in the Omeo goldfield (Dunn 1912, cited in Maher *et al.* 1996). At least four of these veins were developed by the Auro Argentum (Silver King) and Auro Argentum Extended (Comstock) mines.

Recent exploration over old workings (Australian Goldfields NL 1997 March and June Quarterly Reports; Australian Goldfields NL 1997 Annual Report) for open pit resources at

Glen Wills-Sunnyside, just west of the region, in the Mount Wills goldfield has resulted in the delineation of small gold resources (Table 3). A significant component of these resources is on surface in old tailings and waste dumps. The Mount Wills goldfield extends into the western edge of the region (see Map 2).

Recorded production from Glen Wills-Sunnyside, from 1895 to 1963 is estimated at 6.9 tonnes. The gold ore mined was very rich (16 to 211 grams per tonne) and was in quartz reefs and veins that occur in shears and fissures hosted by granite, phyllites and schists along the southeastern contact between the Silurian Mount Wills Granite and the Omeo Metamorphic Complex. The reefs average about 4 per cent sulphides (mainly pyrite and arsenopyrite) that contain a significant amount of finely divided gold so that roasting or bacterial leaching to oxidise the sulphides prior to gold extraction is required. Free gold is also associated with the sulphides. Metallurgical testing has indicated that modern processing techniques could achieve about 85 per cent gold recovery from the sulphide mineralisation (Australian Gold Mines NL 1994).

Base metals

Small to medium scale base metal mining occurred at the Wilga copper-zinc-silver, volcanogenic massive sulphide (VMS) deposit in the Limestone Creek Graben between 1992 and July 1996. Other small base metal deposits and occurrences are common in eastern part of the region and are related to rocks of the Buchan Rift and Limestone Creek Graben (Maher *et al.* 1996). There are 44 base metal occurrences in the region (see Map 2, Table 4).

Volcanic and sedimentary rocks of the Limestone Creek Graben host the small to medium sized Wilga and Currawong base metal deposits. Mining at Wilga ceased in 1996 (Table 5 for production data) but the nearby Currawong deposit has not been mined. Prior to mining, Wilga had proven reserves of 0.64 million tonnes of ore at 9.45 per cent copper, 0.09 per cent lead, 2.39 per cent zinc, 38 grams/tonne silver and 0.16 grams/tonne gold. Currawong has 8.84 million tonnes of measured, indicated, and inferred resources (Table 6 for metal grades). Both of these are the largest known base metal deposits in Victoria. Several other minor base metals occurrences are located in the Limestone Creek Graben (Maher *et al.* 1996).

The first discovery of lead ore in Victoria was made near Buchan, just east of the region, in 1869 (Adams 1981, cited in Maher *et al.* 1996). Several carbonate hosted lead-silver deposits were discovered and mining followed intermittently at Spring Creek, Pyramids and Hume Park until 1928 (Cochrane 1982, cited in Maher 1996). Volcaniclastics of the Fairy Sandstone and Spring Creek Member commonly contain low grade, detrital base metal sulphide grains of exhalative origin (e.g. Shaws Gully). Drilling at Flukes Knob prospect intersected low grade stratiform lead-zinc sulphide mineralisation (Maher *et al.* 1996). Iron and manganese/barite deposits with elevated copper, lead, zinc and silver also at this stratigraphic level (e.g. Oxide and Iron Mask mines). The carbonates and volcaniclastic rocks extend in to the region.

Recent exploration, just north west of the region, has recognised volcanogenic gold-copper and gold-silver-barium mineralisation in altered calc-alkaline andesite lavas at Hill 800 near Jamieson (Maher *et al.* 1997, Fraser 1998). These rocks extend into the region.

Minor amounts of copper, lead, zinc and silver commonly occur with gold mineralisation in the Woods Point-Walhalla gold sub-province.

Table 4 Mineral occurrences, old mines and deposits of the Gippsland region (Map 2)

Locn no.	Name	Easting	Northing	Commodity
1	Straight Running Creek	576350	5944000	AU
2	Cribbage Creek	575500	5943450	AU
3	Sassafras Creek	575500	5943450	AU
4	John's Find	570000	5937700	AU CU
5	Buembah Flat	578500	5937550	AU
6	Mount Murphy Wolfram Mine	588800	5935400	W
7	Mt. Murphy wolfram	588800	5935400	W
8	South Mammoth Lode	569300	5936300	AU
9	Beloka Gold	572520	5932480	AU
10	Spellings Lode	555900	5933300	AG CU PB
11	Quart Pot Flat	555900	5933300	CU,PB,AG
12	Benambra (Wombat Creek)	556800	5932900	LS
13	Wombat Creek	556800	5932900	LS
14	Ralstons Lode	556600	5932800	CU,PB,AG
15	Mitta Mitta River	559000	5931700	CU
16	Gibbo River	559500	5931600	CU PB AG BA
17	Silver Flat	561200	5930800	PB,AG
18	Unnamed Reef	553000	5930000	AU
19	The Surprise Prospecting Party	552410	5929260	AU
20	Wombat Hole	561800	5929400	AU CU
21	Morass Creek	561700	5929300	WO
22	Deep Creek	570200	5928200	AU
23	Limestone Creek	596400	5925300	AU
24	Limestone Creek	596200	5924800	LS
25	Middle Creek — Unnamed no. 3	591500	5922000	AU
26	Unnamed no. 3	591500	5922000	AU
27	Middle Creek — Unnamed no. 4	591000	5921000	AU
28	Unnamed no. 2	591000	5921000	AU
29	Middle Creek — Unnamed no. 5	590100	5920300	AU
30	Unnamed no. 1	590100	5920300	AU
31	Benambra (Stony Creek)	596030	5920100	LS
32	Stoney Creek	596030	5920100	LS
33	Limestone Creek	596000	5920050	DS-Marble
34	Limestone Creek	590100	5916800	CR
35	Austerlitz Ironstone	586800	5912700	FE
36	Brothers	567000	5915000	DS-Granite
37	The Brothers — Syenite	567000	5915000	DST
38	The Brothers	567000	5914000	FS
39	Pyles	564500	5914200	WO-S
40	Invisible Reef	548900	5921528	SN
41	Sloans Reef	549700	5920300	AU
42	Leviathan Reef	549200	5920200	AU
43	Unnamed Dyke	545200	5920950	SN
44	Unknown Reef	536600	5919300	AU
45	Unknown Reef	534400	5917800	AU
46	Wilson's	542000	5912000	AU
47	Tetu	542000	5911800	AU
48	King	542000	5910800	AU
49	Unnamed Reef	541800	5910600	AU
50	King's Brothers	542000	5910600	AU
51	Hall	542200	5910200	AU
52	Chinese no. 2	542200	5909500	AU
53	Mac	542800	5909500	AU
54	Unknown no.1	542800	5908500	AU
55	Unknown no.2	543700	5907300	AU
56	Beveridges	542000	5905000	AU
57	Carkeel's	542000	5905000	AU
58	Molyneaux	542000	5905000	AU
59	Dry Forest Creek	542000	5905000	SN
60	Unknown Reef	531300	5905700	AU
61	Cobungra River	533000	5901000	AU
62	Roseners Reef	507250	5904000	AU
63	Last Rose of Summer	510350	5902250	AU
64	Try Again	511000	5902000	AU
65	Morris Workings	515000	5901700	AU
66	Mammoth	507800	5899600	AU
67	Armours Workings	518300	5897500	AU
68	Evening Star	508800	5897100	AU

Locn no.	Name	Easting	Northing	Commodity
69	Rose of Denmark	509700	5896000	AU
70	Ryans Workings no. 2	511600	5889200	AU
71	G. Worcester	552600	5900250	AU
72	Currawong	580500	5906400	CU,PB,AG,ZN
73	Sutters	577100	5904500	AU
74	Wilga	578300	5904200	CU ZN
75	Bindi (Old Hut Creek)	575600	5895300	LS
76	Bindi (2)	574500	5894500	LS
77	Hells Hate Hole	580820	5894940	AU
78	Bindi (1)	576000	5890000	DS-Marble
79	Terrace Workings	553300	5895800	AU
80	New Polar Star	547400	5894050	AU
81	Polar Star	547400	5894050	AU
82	Daisy	547460	5893910	Unspecified
83	Association	547360	5893810	Unspecified
84	Gambetta	547750	5893700	AU
85	Golden Bar	547614	5891286	AU
86	Mountain Maid Reef	547493	5891165	AU
87	Helvetia	547521	5890924	AU
88	Forsyths Silver Lodes	552000	5889500	PB,AG
89	Silver King	551967	5889502	AG
90	Dalmatia Claim	547900	5888800	AU
91	Puzzle	548403	5888153	AU
92	Comstock Silver Lodes	553200	5887400	PB,AG
93	Unknown #1	555079	5885134	AU
94	The Gem	556357	5882894	AU
95	Unknown #15	555876	5882681	AU
96	The Topaz	556386	5882647	AU
97	Cassilis	552672	5878447	AU
98	Tongio Gold Dredging	555090	5877175	AU
99	Tablelands Reef	510300	5875400	AU
100	Birregun Reef	528500	5873500	AU
101	Republic Reef	528500	5873500	AU
102	Glengarry Mine	506500	5869000	AU
103	Pioneer Reef	505500	5867400	AU
104	Good Hope	509100	5867900	AU
105	Red Rose Battery	517700	5868000	Unspecified
106	Tiger Creek	590700	5868400	CU
107	Tiger Grid	588500	5866000	CU
108	Red Steer Prospect	592564	5862782	CU PB ZN
109	Scorpion Creek Prospect	595060	5861370	CU
110	Gil Groggin Gold Mine	593567	5860629	AU
111	Joes Reef	561900	5861800	Unspecified
112	Ensay Syndicate	566400	5861500	AU
113	Sawyers	566000	5860600	AU
114	Brother Jonathon Reef	507000	5863700	AU
115	Hibernia	516300	5861100	AU
116	Eureka Reef	528800	5860500	AU
117	Kong Meng	515050	5856750	AU
118	Black Snake Creek Battery	511800	5855850	Unspecified
119	Jorgensons	524450	5853900	AU
120	Trail of the Serpent	523750	5853050	AU
121	Perseverance	517800	5852300	AU
122	Blue Leader	519000	5851450	AU
123	Great Eastern	519000	5851450	AU
124	Little Exhibition	518550	5851400	AU
125	Dargo/Exhibition Battery	518200	5851300	Unspecified
126	Exhibition	519100	5851000	AU
127	Dawson City	561500	5855800	AU
128	Hans Reef	563950	5856600	AU
129	Queen	566750	5856625	AU
130	Fainting Range	575600	5855300	MO,W
131	Highland Chief Extension	567600	5850800	AU
132	Great Scott Mine	555000	5849500	AU
133	Black Snake Creek	548500	5849400	AU
134	Sandy Creek	545000	5846180	AU
135	Licola (Dolodrook River)	472500	5844500	LS
136	Dolodrook River	476300	5842000	CR
137	Barkly River (Fullarton Spur)	458678	5840555	PH
138	Licola (Serpentine Creek)	461600	5836200	LS

Locn no.	Name	Easting	Northing	Commodity
139	Budgee Budgee Reef	516200	5836750	AU
140	Evening Star Reef	516200	5836750	AU
141	Granite Creek	516200	5836800	AU
142	Scandanavian Reef	516200	5836750	AU
143	Whitehorse Reef	516200	5836750	AU
144	Beehive Mine	544650	5836050	AU
145	Exhibition Reef	547550	5832450	AU
146	New Enterprise	563000	5839000	AU
147	Lady Seville	563950	5839850	AU
148	Victoria Mine	563300	5839400	AU
149	Echidna Shaft	563450	5839100	AU
150	Victory Shaft	563100	5839000	AU
151	Lanky Tom Creek Prospect	568332	5837910	AU
152	Falls Creek Tin And Gold	583500	5828400	SN
153	Colquhoun	581900	5820200	DS-Granite
154	Swan Reach (Mississippi Creek)	581900	5817200	LS
155	Mississippi Creek	581900	5817200	LST
156	Swan Reach (Tambo River)	577500	5814700	LS
157	Tambo River	577500	5814700	LST
158	Nicholson River	566100	5816100	LS
159	WA70	557650	5820730	LST?
160	Bark Bucket Gully	555200	5826800	AU
161	Mount Taylor	550000	5827500	DS-Granite
162	Mount Taylor	552800	5822000	FS
163	Wy Yung	553350	5815600	LS
164	Bairnsdale	548400	5815100	LS
165	WA457	542950	5813950	LST
166	Lindenow	543000	5813900	LS
167	Iguana Creek	527900	5825000	CU
168	Lees Creek	513000	5832950	AU
169	Crystal Reef	510600	5821300	AU
170	See It Out	510600	5821300	AU
171	Gladstone Creek	510700	5820300	AU
172	Prouds Workings	511000	5819500	AU
173	Boyces Find	514200	5821000	AU
174	Freestone Creek Deep Lead Co.	509800	5815350	AU
175	Freestone Creek	507900	5814800	CU
176	Briagolong	507550	5814750	DS-Sandstone
177	Valencia Creek	496000	5817600	DS-Sandstone
178	Boisdale	496200	5807800	KAO
179	Avon River	506000	5798000	GEM
180	Avon River Jasper	506000	5798000	GEM
181	East Walhalla Cu & Pt Mine	452600	5800600	CO,CU,PGM,AG
182	Cohens Reef, Walhalla	451678	5799575	AU
183	Thomson River Copper Mine	449500	5795600	CU,NI,PGM
184	Toongabbie	457600	5795500	DS-Marble
185	Toongabbie (Marble Creek)	457500	5795500	LS
186	Heyfield	480400	5796500	KAO
187	Maffra	495496	5794602	Unspecified
188	Tyers River (Boola)	449700	5782000	LS
189	Rosedale	477000	5778000	Peat
190	Longford	506400	5773700	LS
191	Dutson	511250	5774400	LS
192	Yallourn	444000	5772000	KAO
193	Coalville	435400	5767800	CBL
194	Morwell	447000	5766000	KAO
195	Morwell	446000	5765000	Peat
196	Merrimans Creek	495200	5765400	LS
197	Childers	423500	5760800	BA,BX
198	Nahoo	431800	5759900	BA,BX
199	Wallaces	425500	5756300	BA,BX
200	Giffard	510700	5754100	Peat
201	Burgess Creek	465800	5755100	BA,BX
202	Jerralang	448400	5755100	BA,BX
203	Peels	445300	5753400	BA,BX
204	Polleys	423399	5753596	Unspecified
205	Smiths Mill	423298	5753196	Unspecified
206	Watkins	426300	5753700	BA,BX
207	Lovells	429601	5752698	Unspecified
208	Sargents	430800	5752700	BA,BX

Locn no.	Name	Easting	Northing	Commodity
209	Boolarra	437500	5752600	BA,BX
210	Boolarra	436000	5751700	CBL
211	Napiers no.1	427900	5751500	BA,BX
212	Paynes	425700	5750900	BA,BX
213	Kings	425699	5750499	Unspecified
214	Harrisons	425900	5750300	BA,BX
215	Wankes	425702	5750200	Unspecified
216	Mirboo North	425779	5749446	FE
217	De Hais	429200	5749000	BA,BX
218	Foys	428400	5748400	BA,BX
219	Prosper Valley	439700	5748800	BA,BX
220	Foxs	438697	5747901	Unspecified
221	Walkers	443299	5749000	Unspecified
222	Bonds	441500	5747800	Unspecified
223	Greenwoods	441400	5747600	BA,BX
224	Roys	441701	5747801	Unspecified
225	Berrys Creek (Mirboo North)	421900	5747200	CBL
226	Tierneys	432404	5745598	Unspecified
227	Martins	431202	5745299	Unspecified
228	Crutchfields	431901	5745205	Unspecified
229	Woodside (Bruthen Creek)	484900	5742800	LS
230	Darriman	491600	5742000	LS
231	Korumburra (Coal Creek)	397200	5744500	CBL
232	Jumbunna	393200	5740000	CBL
233	Outtrim	392000	5738900	CBL
234	Gelliondale	466100	5725500	BA,BX
235	Gelliondale	464200	5721800	Peat
236	Toora	442501	5725203	SN CST
237	Toora	438000	5721600	GEM
238	Foster (Stockyard Creek)	427600	5722900	CBL
239	Hoddle Range	422999	5711699	PH
240	Wilsons Promontory	452769	5703930	CST
241	Waratah Bay	415000	5703400	PGM
242	Ten Mile Creek	407200	5701900	LS
243	Walkerville	412800	5698500	LS
244	Walkerville (Digger Island)	413300	5696800	LS
245	Yanakie	436300	5689500	LS
246	Yanakie (South)	436400	5689000	LS
Outside Gippsland region boundary				
247	East Area no.1 & 2 (Wonthaggi)	377600	5723900	CBL
248	East Area no.3 (Wonthaggi)	379100	5725000	CBL
249	No.18 Shaft (Wonthaggi)	380500	5725400	CBL
250	Central Area (Wonthaggi)	375700	5725700	CBL
251	Mcbride Tunnel (Wonthaggi)	375200	5727100	CBL
252	West Area (Wonthaggi)	373000	5727300	CBL
253	Kirrak Area (Wonthaggi)	381000	5727300	CBL
254	No.20 Shaft (Wonthaggi)	375200	5729300	CBL
255	Powlett (Wonthaggi)	375700	5728800	CBL
256	Dudley Area (Wonthaggi)	375200	5728800	CBL
257	Unnamed	375199	5729297	AU
258	Bass River	378000	5747000	GEM
259	Lang Lang	380289	5759109	SI
260	Cora Lynn	379400	5774800	Peat
261	Tynong	379600	5784650	DS-Granite
262	Tynong	384500	5790900	FS
263	Bunyip River	392434	5794350	SN CST
264	Nayook	392600	5795500	FS
265	Neerim South (Jindivick)	406500	5790000	SB
266	Yarragon	417300	5775100	Peat
267	Trafalgar East	427400	5773500	Peat
268	Morning Star (Woods Point)	433497	5841301	AU CU PB
269	A1 Mine	429450	5848800	AU
270	Gaffneys Creek	429271	5851230	AU
271	Rhyolite Creek	446400	5862300	PY
272	Rhyolite Creek	448684	5864297	AU
273	Gannans Prospect (Kevington)	433800	5866600	SB
274	Jamieson River (Quicksilver Creek)	438200	5868600	HG
275	Mitchell Creek (Howqua)	440701	5875295	DST
276	Great Rand Mine	440900	5882140	AU

Locn no.	Name	Easting	Northing	Commodity
277	Cameron Creek	442300	5882700	CU
278	Mount Smythe	507100	5904700	FS
279	Mystery Reef no. 2	505900	5905800	AU
280	Sambas	504500	5913850	AU
281	Ruby Creek	510800	5908000	AU
282	Talgarno	510800	5908000	AU
283	Unknown Reef	513900	5909200	AU
284	Murphy Creek	518200	5906000	AU
285	Unknown Reef	520800	5909000	AU
286	Unknown Reef	523800	5908500	AU
287	Unknown Reef	529000	5911500	AU
288	Unnamed Reef	521100	5913200	AU
289	Champion	509500	5913000	AU
290	Calliope Reef	510000	5913000	AU
291	Razorback Line	510900	5912800	AU
292	Government Grant Reef	511000	5912500	AU
293	Mountaineer Reef	512000	5912000	AU
294	One Alone Line	512500	5911100	AU
295	Red Robin	513800	5911650	AU
296	Red Robin Mine	516074	5911771	AU
297	Unnamed Reef	517300	5912000	AU
298	Unnamed Reef	517100	5913400	AU
299	Unnamed Reef	519000	5912900	AU
300	Unnamed Reef	518600	5914100	AU
301	Oven's River Deep Lead	507430	5919900	AU
302	Unknown Reef	511850	5920800	AU
303	Unnamed Reef	516200	5921800	AU
304	Unnamed Alluvial	517600	5919300	AU
305	Unnamed Alluvial	517400	5920800	AU
306	Unnamed Reef	521900	5915200	AU
307	Unnamed Reef	527300	5917800	AU
308	X: Anaconda Prospect	525300	5920300	AU
309	Unnamed Reef	529300	5920200	AU
310	Unknown no.8	527100	5926000	AU
311	Unnamed Reef	528600	5926600	W
312	Unknown no.13	529700	5928300	AU
313	Unknown no.14	530500	5928800	AU
314	Unknown no.9	525000	5929700	AU
315	Unknown no.10	527000	5931800	AU
316	Unknown no.11	527300	5929800	AU
317	Unknown no.12	528200	5930200	AU
318	Unknown no.3	536800	5926000	AU
319	Unknown no.4	538200	5924500	AU
320	Unnamed no.1 Dyke	541200	5930800	SN
321	Unnamed no.2 Dyke	542900	5929900	SN
322	Mopoke Creek	547100	5929300	AU
323	Peg Leg Creek	551700	5929070	AU
324	Wombat Creek	552400	5929700	BI,SN
325	Unnamed Reef	553700	5931600	AU
326	Unnamed Reef	553900	5932800	AU
327	Mt. Wills Creek	539000	5935400	AU
328	Merrimae Creek	545500	5935000	AU
329	Conglomerate Grid	554200	5935400	AU
330	Conglomerate Prospect	554200	5935400	CU PB ZN
331	Proctors Claim	564500	5933550	AU
332	Dejarlias Claim	564600	5933600	AU
333	Donovan's Creek	556900	5940050	AU AG
334	Silvertop Grid	560350	5943900	AU
335	White Stone Reef	558050	5947020	AU
336	Kangaroo	557700	5948600	AU
337	Lyrebird	558000	5948600	AU
338	Ajax	558430	5950210	AU
339	Mcraes Claim	564200	5951500	AU
340	Daddy of the Dark	566350	5955300	AU
341	South Mascotte	569650	5952800	AU
342	Mascotte Extended Co.	569500	5953200	AU
343	Mountain Maid Claim	569000	5953275	AU
344	Great Extended Mascotte	569600	5953400	AU
345	Federation	569600	5953400	AU
346	Mascotte	569525	5953450	AU

Locn no.	Name	Easting	Northing	Commodity
347	La Mascotte	569525	5953450	AU
348	Mountain Bell Mine	570200	5953800	AU
349	Mountaineer	569400	5954100	AU
350	The Trusty	569875	5954350	AU
351	Golden Crown South	569475	5954515	AU
352	Young Australia	569925	5954980	AU
353	President Garfield	569290	5955025	AU
354	Golden Crown	569260	5955025	AU
355	Argyle	569410	5955125	AU
356	Normanby	569850	5955330	AU
357	Golden Crown North	569325	5955550	AU
358	Legacy Mine	570775	5955550	AU
359	Comstock Extended	569660	5956000	AU
360	The Pryde	569900	5956080	AU
361	Maffra	569700	5956120	AU
362	Crown	571155	5956245	AU
363	Duke of York	570795	5956280	AU
364	Weardale	570025	5956280	AU
365	Comstock	569575	5956360	AU
366	United Miners	569610	5956420	AU
367	The Gift	569415	5956425	AU
368	Victoria	569225	5956250	AU AG
369	Mt Peters North	569225	5956305	AU
370	Glenloth	570850	5956615	AU
371	Shamrock	570660	5956830	AU
372	Good Friends	569910	5956840	AU
373	Tarcoola	570000	5956890	AU
374	Sir Wilfred Lawson	569600	5956895	AU
375	Mitta Mitta	569225	5956875	AU
376	Peter Lalor	569210	5956960	AU
377	Hillsborough	569610	5956980	AU
378	Graeme Barrington	570730	5957000	AU
379	New Glengarry	570575	5957050	AU
380	Glengarry	570510	5957190	AU
381	Albion	569940	5957175	AU
382	Mt Elliot	570550	5957330	AU
383	Glen Dart Extended East	570375	5957500	AU
384	Glen Dart North Extended	570360	5957390	AU
385	Homeward Bound	570375	5957430	AU
386	Corio Bay	569675	5957360	AU
387	Brian Boru	569020	5957280	AU
388	Spread Eagle	569340	5957500	AU
389	Dark River Extended	569340	5957560	AU
390	Macduff	568980	5957565	AU
391	Perseverance	568975	5957750	AU
392	Dark River	569360	5957675	AU
393	Sir John Madden	569665	5957625	AU
394	Garryowen Mine	570310	5957575	AU
395	Loch Sloy	570330	5957705	AU
396	Hidden Treasure	569915	5957860	AU
397	Virtue	569575	5957890	AU
398	Dark River Favourite	570000	5958080	AU
399	Dawn of Day	570075	5958115	AU
400	Tomahawk	570265	5958420	AU
401	Dart River Mine	570200	5958500	CU
402	Emu	585050	5948750	AU
403	Ethel Jane Reef	588700	5957500	AU
404	Tin Creek	593800	5965600	AU
405	Surveyors Creek Tinfield	594500	5966200	SN
406	Alluvial Flat	594700	5966600	AU
407	Sunday Creek	594800	5966800	AU
408	Camp Creek	595100	5966800	AU
409	Unnamed Sluiced Area	595500	5966600	AU SN
410	Farden's Creek	595500	5966800	AU
411	Native Dog Plain	596400	5916100	CU
412	Native Dog Flat	596400	5916100	CU
413	Jame's Flat	599700	5912800	CU PB
414	Upper Buchan River Pyrite	604514	5898769	FE
415	Wulgumerang	604000	5895400	WO
416	W-Tree/Gelantipy	609000	5867000	GEM

Locn no.	Name	Easting	Northing	Commodity
417	W-Tree Creek Prospect	607622	5862289	AU
418	W-Tree Creek	607600	5862300	PY-?
419	Rocky Camp (Buchan)	606300	5853600	LS
420	Pyramids Mine	607200	5853800	PB,ZN
421	Shaws Gully Prospect	608264	5854052	PB,ZN
422	Hume Park Mine	608700	5850100	PB,AG
423	Spring Creek	602300	5848400	CU,PB
424	East Buchan Thrust Prospect	606776	5847056	CU
425	Cocks Limonite	607100	5846700	FE
426	Oxide Mine	605700	5844700	FE,MN
427	Buchan South	600150	5843100	LS
428	Cameron's Quarry	600150	5843100	DST
429	Buchan South (Cameron's)	600150	5843101	DS-Marble
430	Dogwood Prospect	589000	5841000	CU
431	Flukes Knob Prospect	595000	5838500	PB ZN
432	Tallatoorook	596400	5837700	CU,PB
433	Good Hope Mine	596300	5837300	BA
434	Kanni Creek	597600	5836800	BA
435	Iron Mask	601250	5837100	PB,ZN,FE,MN,BA
436	Blue Spur	601000	5835700	PY
437	Seven Mile Deposit	599300	5832100	FE
438	Six Mile Deposit	599340	5831340	FE
439	Five Mile Deposit	598250	5830750	FE
440	Five Mile	598250	5830750	FE
441	Nowa Nowa	598400	5830700	LS
442	Colquhoun Granite Quarry	588500	5829500	DST
443	Two Mile Deposit	596100	5826800	FE
444	Two Mile	596100	5826800	FE
445	Nowa Nowa	599600	5826700	PY-?
446	Three Mile	599600	5826700	FE
447	Nowa Nowa	595000	5825000	GEM
448	WA86	596420	5825000	LST?
449	WA357	599600	5820500	LST

Table 5 Recorded past production of other commodities in the Gippsland region

Map 2 mineral occur. locn	Mine/quarry/prospect	Material (tonnes)	Contained commodity (tonnes)	Period	Source
74	Wilga	954 989	44 968 Cu 21 031 Zn >10.14 Ag	1992–96	Maher <i>et al.</i> (1996)
97	Cassilis — copper ore	17	na	1909	Cochrane (1982), cited in Maher <i>et al.</i> (1996)
	Deddick lead ore	20	na		Cochrane (1982), cited in Maher <i>et al.</i> (1996)
	Various carbonate base metals mines – lead ore	796	na		Maher <i>et al.</i> (1996)
6	Mount Murphy Mine	90.4	Tungsten concentrate		Oppy <i>et al.</i> (1995)
136	Dolodrook River	200	Chromite ore		VandenBerg (1977)
	Howqua Hills (just west of the region)	83	Talc ore	1948–49	VandenBerg (1977)
183	Thomson River	9 000–10 000 2 500	>10% Cu 3.75% Cu 0.34% Ni 12.8g/t Ag 1.5g/t Au 2.3g/t Pt 3.8g/t Pd	1874–81 1882–1913	
		700	n/a	1966–71	Cochrane (1982), cited in Maher <i>et al.</i> (1996)

Table 6 Other mineral resources of the Gippsland region

Map 2 mineral occur. locn	Mine/quarry/ deposit/prospect	Material (tonnes)	Grade	Contained commodity (tonnes)	As at	Source
72	Base Metals					
	Currawong Measured	510 000	1.69% Cu	8 619	30/6/94	Denehurst Annual Report 1994
			0.87% Pb	4 437		
			3.23% Zn	16 473		
			41 g/t Ag	20.91		
	Indicated	7 640 000	1.22 g/t Au	0.6222	30/6/94	Denehurst Annual Report 1994
			1.97% Cu	150 508		
			0.65% Pb	49 660		
			4.03% Zn	307 892		
			38 g/t Ag	290.32		
	Inferred	690 000	0.8 g/t Au	6.112	30/6/94	Denehurst Annual Report 1994
			1.9% Cu	13 110		
			0.7% Pb	4 830		
			3.9% Zn	26 910		
			38 g/t Ag	26.22		
	Includes: L1&M1Lens Measured	610 000	0.7 g/t Au	0.483	30/6/95	Denehurst Annual Report 1995
			3.02% Cu	18 422		
			0.64% Pb	3 904		
			4.33% Zn	26 413		
	Indicated	1 040 000	40 g/t Ag	24.4	30/6/95	Denehurst Annual Report 1995
			1.58 g/t Au	0.9638		
			3.18% Cu	33 072		
			0.74% Pb	7 696		
			4.62% Zn	48 048		
	Inferred	140 000	41 g/t Ag	42.64	30/6/95	Denehurst Annual Report 1995
			1.47 g/t Au	1.5288		
3.3% Cu			4 620			
0.9% Pb			1 260			
4% Zn			5 600			
49 g/t Ag			6.86			
		1.85 g/t Au	0.259			
	Iron Ore					
	Nowa Nowa incl (just east of the region):	6 000 000	51.5% Fe		1959	Mitchell Cotts Projects (1988), cited in Maher <i>et al.</i> (1996)
443	Two Mile	11 000–50 000	62.1% Fe ₂ O ₃		1959	Nott (1980), cited in Maher <i>et al.</i> (1996)
439	Five Mile	4 690 000	52% Fe		1959	Mitchell Cotts Projects (1988), cited in Maher <i>et al.</i> (1996)
437	Seven Mile	930 000	48.9% Fe		1959	Mitchell Cotts Projects (1988), cited in Maher <i>et al.</i> (1996)
	McRae’s Limonite Quarry	6 800 000	32% Fe			Bowen (1970), cited in Maher <i>et al.</i> (1996)
			<10% Mn			Cochrane (1982), cited in Maher <i>et al.</i> (1996)
	Copper & Platinoids					
183	Thomson River	18 900	2.4% Cu			Cozens (1973), cited in VandenBerg <i>et al.</i> (1995)
			0.9g/t Au			
			7.6g/t Ag			
			1.7g/t Pt			
			4.4g/t Pd			

Copper and platinum group metals

Copper was first mined around 1864 from the Thomson River Copper Mine and copper was also the primary product of the East Walhalla copper and platinum mine, both near the western boundary of the region. A number of gold mines associated with the Woods Point dykes, extending into the western edge of the region, have produced copper and platinum group metals as by-products. At least ten dykes in the sub-province are mineralised, and for each 1 per cent of copper there is 1 gram/tonne gold, 1 gram/tonne palladium and probably 1 gram/tonne platinum (Keays & Green 1974). Principals amongst these are Hunt's, the Shamrock and Morning Star mines (VandenBerg *et al.* 1995).

Intermittent operations at the Thomson River mine prior to 1971 gave a total estimated production of about 13 000 tonnes of ore (Cochrane 1982, cited in Maher *et al.* 1996). The

only profitable period of production was from 1874 to 1881, but mining continued until 1913. Very small production occurred from 1966 to 1971 (Table 5) and a small resource remains (see Table 6).

The East Walhalla copper and platinum mine produced small amounts of ore from three small open-cuts and a short underlay shaft, but no production details are known. Small amounts of platinum and osmiridium are found with alluvial gold at Turtons Creek, Foster and in beach sands at Waratah Bay (Douglas 1984).

Tin

There are 22 primary (hard rock) and alluvial tin occurrences in the region (Map 2, Table 4).

Alluvial tin deposits

Alluvial tin (plus minor gold) workings on several creeks east of Bruthen were reported by Herman 1899 (cited in Maher *et al.* 1996). Alluvial tin is found as the mineral cassiterite at Toora, Yanakie and Wilsons Promontory. The Toora field was first worked in the 1870s and lies in Tertiary age gravel. Several companies worked this field up to 1939 to produce 400 tonnes of concentrate (Cochrane 1971, in Douglas 1984). Alluvial tin mining occurred at Mount Hunter, on Wilsons Promontory from 1920 to 1934, but failed because of poor values (Douglas 1984).

Primary tin deposits

Primary greisen tin deposits in the eastern part of the region occur at the southern end of the elongate north-south trending Mount Tallebung (NSW) – Albury – Mount Wills Tin Province (Cochrane & Bowen 1971, cited in Oppy *et al.* 1995). These deposits are associated with Middle Silurian to Lower Devonian aplite-pegmatite dykes, as in the Walwa and Mitta Mitta dyke swarms. Mineralisation is due to hydrothermal alteration (predominantly greisenisation).

Tungsten

There are four tungsten occurrences in the region (see Map 2, Table 4). Much of Victoria's tungsten production was from the Mount Murphy Wolfram mine, in the north east corner of the region, where a total of 90.4 tonnes of tungsten concentrate was produced from 1908 to 1920.

Wolframite (tungsten mineral) was mined at the Fainting Range mine until about 1945. The mine was discovered before 1920, and produced an unknown quantity of tungsten (Thomas & Crohn, 1951, cited in Maher *et al.* 1996). The mine consisted of three open cut/adit workings developed on four quartz veins. Mineralised veins are controlled by faults in locally altered schists, and dip between 64° and 70° in several directions. Molybdenum also occurs here.

Iron ore

At Narracan, limonite with 36 per cent iron has formed on ferruginous grit and sandstone. Highly ferruginous Tertiary age gravel and clay containing 79 per cent iron occurs at Mirboo North. A small deposit of limonite derived from basalt at Alberton West has 44 per cent iron and bog iron at Inverloch contains 11 per cent iron (Douglas 1984). There are 13 iron occurrences in the region (see Map 2, Table 4).

Early gold prospecting in 1887 led to mining of iron ore deposits north of Nowa Nowa, just east of the region (Stirling 1887, cited in Maher *et al.* 1996). Similar rocks extend into the region. Production from these, and manganese oxide deposits since that time has been intermittent and small. The highest grade deposits are magnetite-hematite bodies and five main deposits called Two Mile, Three Mile, Five Mile, Six Mile and Seven Mile have been identified. These deposits have a resource exceeding six million tonnes at 51.5 per cent iron (Mitchell Cotts Projects 1988, cited in Maher *et al.* 1996). Resource data for individual deposits are shown in Table 6. Several drill intersections have also indicated potential for gold-copper resources associated with the magnetite-hematite bodies.

Chromite

Some 200 tonnes of chromite ore has been taken from the Dolodrook River serpentinite (VandenBerg 1977). Chromite also occurs at the Howqua River Chromium Field, just west of the region, in Cambrian greenstones that extend into the region.

Bismuth

Alluvial bismuth is an accessory to alluvial tin and gold in the Mount Wills goldfield (Oppy *et al.* 1995) at several locations.

Antimony

There are five significant antimony occurrences in the region in addition to gold occurrences that often contain minor antimony (Map 2 and Table 4). Antimony ore has been extracted at the Big River mine in the northern part of the Woods Point-Walhalla gold sub-province, adjacent to the region. Here, several adits and open pits have been excavated on small reefs in sedimentary rocks adjacent to an early Devonian lamprophyre dyke. About 500 kilograms of concentrate was produced and ore samples taken in 1964 assayed 43 per cent to 53 per cent antimony (Maher *et al.* 1997). Similar host rocks extend into the region.

Silver

Silver has been recorded in association with lead at a number of localities including Silver Flat, Quartz Pot Flat (both near the north-west boundary of the region) and the Mammoth Complex. Silver associated with galena, is generally hosted by fissure quartz veins and breccias at or near the contact of major faults (Oppy *et al.* 1995).

Significant silver production as a by-product of gold mining occurred at the Maude and Yellow Girl mine (just northwest of the region), in the Mt Wills goldfield where 53.8 kilograms of silver was recovered during the period 1962–1967 (Oppy *et al.* 1995).

Non metals

Brown coal

Very large brown coal resources are present within the Latrobe Valley Depression of the Gippsland Basin, which covers much of the southeastern part of the region. Total reserves for the Gippsland Basin have been estimated at 96 300 million tonnes, while total resources have been calculated at over 172 874 million tonnes (Gloe & Holdgate 1991). Resources of the major deposits mentioned below and a number of other significant deposits in the region are shown in Table 7.

Table 7 Brown coal resources of the Gippsland region

Map 2 coalfield number	Mine/deposit	Brown coal (Mt)	Source
	Gippsland Basin		
C1	Gippsland Basin Fringe Areas	80 000	Kinhill (1982)
C1	Deep Gippsland Basin	221 400	Holdgate (1984, cited in Gloe & Holdgate 1991)
C2,C3	Moe Swamp Basin		
	Yarragon (C2) and Moe(C3) Coalfields	773	Stanley (1986)
C4	Latrobe Valley Coal Field		
	Budgerie — inferred	230	Kinhill (1982)
	Coolungoolan — indicated	1 072	Kinhill (1982)
	Driffield — Narracan — measured	5 566	Kinhill (1982)
	Flynn Railway Station — indicated	3 000	Kinhill (1982)
	Gormandale — measured and indicated	3 100	Kinhill (1982)
	Hazelwood Mine — indicated	8 882	Kinhill (1982)
	Holey Plains — indicated	3 295	Kinhill (1982)
	Loy Yang Mine — measured and indicated	17 660	Kinhill (1982)
	Maryvale — measured	10 053	Kinhill (1982)
	Morwell		
	M1 Seam — measured	1 651	Kinhill (1982)
	M2 Seam — measured	584	Kinhill (1982)
	Rosedale — measured and indicated	9 300	Kinhill (1982)
	Traralgon — measured and indicated	5 919	Kinhill (1982)
	Tyers South — indicated	1 828	Kinhill (1982)
	Willung — indicated	2 596	Kinhill (1982)
	Yallourn Mine — measured	430	Kinhill (1982)
	Yinnar — indicated	2 860	Kinhill (1982)
C5	Stradbroke Coalfield		
	Stradbroke — indicated	3 700	Kinhill (1982)
C5	South Gippsland Basin		
	Boodyarn — inferred	276	Kinhill (1982)
	Won Wron — measured	12	Kinhill (1982)
C6	Gelliondale — Alberton Coalfield		
	Alberton — indicated	4 887	Stanley (1986)
	Gelliondale — indicated	1 700	Stanley (1986)
	— inferred	3 500	Stanley (1986)
C7	Koo-Wee-Rup Coalfield	-	-

Brown coal was first discovered in the Latrobe Valley at Yallourn in 1873. In 1890 a borehole at Morwell intersected 300 metres of coal, mainly in six seams within the Yallourn and Morwell Formations. Coal located at Yallourn North in 1879 became the first major development of brown coal in the Latrobe Valley and intermittently produced a total of 18 million tonnes of brown coal before closing in 1963 (Gloe & Holdgate 1991).

The large Yallourn open cut produces brown coal from the 60 metre thick Yallourn seam. To the south, production from the Morwell open cut is based on the thick (up to 165 metres thick) Morwell 1 seam, which is underlain at depths of 15 to 25 metres by the 55 metre thick Morwell 2 seam. Some 12 500 million tonnes of coal have been proved in the Yallourn-Morwell area but towns, transport corridors, national parks and other constraints restricts potential resource development (Gloe & Holdgate 1991).

Further east in the Loy Yang open cut area the Yallourn and Morwell coal seams are underlain (at about 60 metres depth) by the 60 metre thick Traralgon 1 seam. In places the seams coalesce to form thickness up to 230 metres of low ash, excellent quality brown coal (Gloe & Holdgate 1991).

Production between 1923–1998 from the Morwell, Yallourn, Yallourn North, Yallourn North Extension and Loy Yang mines totals around 1 333 million tonnes (Barton *et al.* 1992, BRS estimate 1997, NRE Annual Reports 1996–1998). Brown coal in Victoria is mainly used for electricity generation, but briquettes are also produced for industrial and domestic use.

A small part of the brown coal bearing Moe Swamp Basin (sub-basin of the Gippsland Basin) encroaches onto the southwest corner of the region. Significant resources of brown coal are known to occur in the Basin within two major coal seams of the Yarragon Formation. The Moe brown coalfield has reserves of 104 million tonnes and resources of 573 million tonnes (Holdgate 1984, cited in Gloe & Holdgate 1991). Further reserves of 200 million tonnes (Stanley 1986) are present in the Yarragon Formation near the town of Yarragon. Total resources for the Moe Swamp Basin are 773 million tonnes. No production has been recorded from the Moe Swamp Basin coals given the larger, more accessible brown coal deposits further east in the Latrobe Valley Depression.

Black coal

Past production from black coal seams has been from scattered deposits in the southwest part of the region but mainly from deposits in the Wonthaggi area just to the southwest of the region (Map 2). Past production and remaining resources data are shown in Tables 8 and 9. The coal is a banded bituminous type with medium moisture and volatile content, and medium to high ash content. It is of good steaming quality and was used for power stations and locomotive boilers (Knight 1988).

Table 8 Black coal resources of the Gippsland region

Map 2 coalfield/ mineral occur. location	Mine/deposit	Material (Mt)	Source
C8	Wonthaggi	6.80	Knight 1988
C8	Korumburra	1.63	Knight 1988
C8	Jumbunna	0.15	Knight 1988
C8	Outtrim	0.10	Knight 1988
C8	Kilcunda-Wollamai	0.15	Knight 1988
C8	Cape Paterson	0.04	Knight 1988
C8	Mirboo North – Berrys Creek	0.50	Knight 1988
C8	Coalville	0.10	Knight 1988

Table 9 Black coal production of the Gippsland region

Map 2 coalfield/ mineral occur. location	Mine/deposit	Material (Mt)	Period	Source
C8	Wonthaggi	17.100	1909–1968	Knight 1988
C8	Korumburra	2.000	1893–1962	Knight 1988
C8	Jumbunna-Outtrim	3.000	1894–1962	Knight 1988
C8	Kilcunda-Wollamai	0.522	1910–1966	Knight 1988
	Coalville	0.063	1884–1897	Knight 1988
	Mirboo North – Berrys Creek	0.003	1928–1929	Knight 1988

Black coal was mined at Wonthaggi from 1909 to 1968 from the lower (2.2 metres thick) of two persistent seams in the Kirrak Basin and two of eight seams in the nearby Dudley Basin. Total Wonthaggi production was 17 070 780 tonnes of coal. Faulting and mechanisation difficulties made mining uneconomical once the thicker seams were worked out (Knight 1988).

Smaller scale production from within the region occurred in the Korumburra, Jumbunna-Outtrim, Kilcunda-Woolamai coal fields, and at Coalville and Boolarra. Production ranged

from two million tonnes at Korumburra down to 500 tonnes at Boolarra and occurred from 1884 to 1966 (Knight 1988).

Oil

Oil was accidentally discovered in a water well at Lakes Entrance in 1924 (Map 2) and minor production (3 063 barrels) occurred from numerous wells from 1930 to 1941 (Boutakoff 1964, cited in Smith 1988). A further 4 935 barrels were produced between 1948 and 1951 from the Lakes Entrance Oil Shaft (Beddoes 1973, cited in Smith 1988).

The offshore potential for oil and gas was recognised in the mid 1950s and subsequent exploration identified the very large oil resources in the Upper Cretaceous to Lower Tertiary age rocks of the Latrobe Valley Group under Bass Strait. The onshore equivalents of these rocks contain extensive brown coal deposits. Numerous onshore exploration wells (67 to the end of 1987) were drilled in east Gippsland during the 1960s, but none were successful (Smith 1988).

Peat

At Morwell, peat of thicknesses up to a few metres occurs in overburden above brown coal measures, but its use in horticulture is limited because of acidity.

Sedge peat (formed in reedy swamps) is produced for horticultural use and potting mixes from a peat swamp north of Yarragon, just west of the region. The silty peat varies from 2 to 7 metres thick along a two kilometre section of a stream. Compaction through drainage may have occurred in possibly extensive peat deposits associated with the rest of the large Moe Swamp Basin, on the western edge the region. (McHaffie & Buckley 1995).

Limestone

Silurian limestone occurs in the Limestone Creek Graben, in the northwest of the region where it occurs as large megaclasts in the Cowombat Siltstone. Analysed samples contain up to 97 per cent calcium carbonate (CaCO_3) (McHaffie & Buckley 1995).

The Lower Devonian Buchan Caves Limestone occurs in the Gippsland region in the Bindi Graben. East of the region the Buchan Caves Limestone in the Buchan Rift is a major limestone resource because of its relatively high purity and the extent of its outcrop. The occurrence consists of almost pure limestone and dolomitic limestone 180–210 metres thick (Teichert & Talent 1958, cited in Maher *et al.* 1996). The limestone is currently quarried at Rocky Camp for production of quicklime, flux, stockfeed, paper manufacture and other agricultural purposes (McHaffie & Buckley 1995, cited in Maher *et al.* 1996). The Murrindal Limestone also occurs in the Buchan Rift. It is pale to dark grey limestone with interbedded mudstone and has a maximum thickness of 250 metres (Maher *et al.* 1996). Murrindal Limestone may also be present in subcrop in the Gippsland region.

Limestone deposits of Silurian and Devonian age have also been recognised at Morass Creek and Wombat Creek and are potential sources for limestone extraction. The Silurian Wombat Creek Group limestone occurs as west-north-west trending lenses near the junction of Gibbo River and Wombat Creek. A 70 metres thick deposit of limestone occurs at Wombat Creek, west of the Mitta Mitta – Gibbo River junction, and contains 97 per cent CaCO_3 (VandenBerg 1988). Future extraction is precluded by their inclusion within the Alpine National Park.

Limestone is also extracted from the Boola Quarry (north of Tyers) for lime production in Traralgon. Limestone of the same age has been extracted for use in paper manufacture at Maryvale from the Tyers and Boola quarries, where several million tonnes of reserves are estimated (Douglas 1984). A high grade limestone body of about 1.6 million tonnes and up to 80 metres thick has been identified within the several million tonnes (McHaffie 1980, in McHaffie & Buckley 1995). The Boola and old Tyers quarries lie in a 2.4 kilometre long belt of limestone along the Tyers River. Further north, just west of the region, minor Devonian limestone resources at Coopers Creek (Evans Quarry) have been worked for lime and ornamental stone, and there are limestone occurrences at Toongabbie (Marble Creek) and Licola (Serpentine Creek), in the south-west of the region. Parts of the Coopers Creek Limestone are potential quarriable sources of high to very high grade limestone. A major part of this limestone is in the Tyers Regional Park. The extractive industry is not necessarily excluded from the Park (McHaffie & Buckley 1995).

Lower Devonian limestone at Walkerville, on Waratah Bay, was burned for lime. Talent (1959, cited in Douglas 1984) estimated reserves of about 500 000 tonnes and two samples analysed gave 95 per cent CaCO_3 with fairly high magnesia and silica contents.

The Tertiary age Gippsland Limestone outcrops in the southern part of the region and reaches a maximum thickness of 500 metres onshore. The constituent Bairnsdale Limestone Member is quarried in the south and just east of the region for aggregate and agricultural purposes (McHaffie & Buckley 1995, cited in Maher *et al.* 1996).

Gippsland limestone has been quarried at Merriman Creek and Darriman (McHaffie 1976, cited in Douglas 1984). It is used in cement manufacture and agricultural lime production. Quaternary calcareous dunes, now within the Wilsons Promontory National Park, have been quarried for agricultural lime (Douglas 1984).

Silica

Quaternary dune sands and alluvial sands of Tertiary age are present within the Gippsland region. At Lang Lang, just west of the region, sand deposits of similar ages have supported a major operation extracting sand for glass manufacture since the 1950s. Both Quaternary age dune sands and Tertiary age alluvial sands are extracted, but the latter less-pure product has become more important as the dune sands are depleted. Production averages 240 000 tonnes per year (McHaffie & Buckley 1995).

Construction materials

As at November 1998, there were 69 current and five applications for construction material Work Authorities in the region. A total of 41 Work Authorities extract sand/gravel, 12 extract basalt and the rest extract limestone, sedimentary rocks, clay/shale and granite. A detailed list of these tenements is shown in Table 10. Numerous smaller pits used for minor rural road maintenance are not covered by these Work Authorities. Construction materials worth approximately \$2.2 million were extracted in 1994–95 under the *Extractive Industries Development Act 1995* (NRE records).

Granite aggregate is extracted from the Sarsfield Granite, north of Bairnsdale, and granitic rocks are extracted at new quarries in the Tynong North area, just west of the region (McHaffie & Buckley 1995). Rhyodacite aggregate is quarried from the Snowy River Volcanics near Nowa Nowa, just east of the region but production is relatively small. All these rock types may extend into the region.

Table 10 Construction materials tenements in the Gippsland region

Map 2 locn	Name	Work authority number	Commodity	Map 2 locn	Name	Work authority number	Commodity
1	The Brothers	WA536	Granite	84		WA178	Basalt Old
2		WA797	Volcanic Tuff	85	Darriman	WA307	Limestone
3		WA274	Basalt Old	86	Darriman	WA307	Limestone
4		WA692	Sand/Gravel	87		WA161	Basalt Old
5		WA626	Sand/Gravel	88		WA161	Basalt Old
6		WA848	Sand/Gravel	89		WA443	Basalt Old
7		WA623	Sand/Gravel	90		WA443	Basalt Old
8		WA70	Granite	91		WA167	Basalt Old
9		WA707	No longer current	92		WA167	Basalt Old
10		WA710	No longer current	93		WA196	Basalt Old
11		WA709	No longer current	94		WA120	Sand/Gravel
12	Lindenow	WA457	Limestone	95		WA446	Sand/Gravel
13		WA494	Sand/Gravel	96		WA446	Sand/Gravel
14		WA243	Sand/Gravel	97		WA57	Sand/Gravel
15	Valencia Creek	WA497	Sedimentary	98		WA451	Sand/Gravel
16		WA143	Sedimentary	99		WA451	Sand/Gravel
17		WA83	Basalt Old	100		WA517	Sedimentary
18		WA83	Basalt Old	101		WA495	Sedimentary
19		WA146	Sand/Gravel	102		WA287	Sedimentary
20		WA747	No longer current	103	Ten Mile Creek	WA1	Limestone
21		WA403	Sand/Gravel				
22		WA136	Sand/Gravel	Outside Gippsland region boundary			
23		WA136	Sand/Gravel	104		WA212	Sand/Gravel
24		WA318	Basalt Old	105		WA424	Sand/Gravel
25		WA318	Basalt Old	106		WA512	Clay/Clayshale
26		WA356	Sand/Gravel	107		WA513	Sand/Gravel
27		WA356	Sand/Gravel	108		WA520	Sand/Gravel
28	Tyers River (Boola)	WA541	Limestone	109		WA512	Clay/Clayshale
29		WA691	Limestone	110		WA469	Sand/Gravel
30		WA91	Basalt Old	111		WA532	Sand/Gravel
31		WA295	Basalt Old	112		WA784	Sand/Gravel
32		WA187	Sedimentary	113		WA470	Sand/Gravel
33		WA458	Sand/Gravel	114		WA470	Sand/Gravel
34		WA69	Clay/Clayshale	115		WA470	Sand/Gravel
35		WA697	Sand/Gravel	116		WA470	Sand/Gravel
36		WA765	No longer current	117		WA210	Sand/Gravel
37		WA311	Sand/Gravel	118		WA538	Sand/Gravel
38		WA311	Sand/Gravel	119		WA210	Sand/Gravel
39		WA448	Sand/Gravel	120		WA283	Sand/Gravel
40		WA448	Sand/Gravel	121		WA283	Sand/Gravel
41		WA266	Sand/Gravel	122		WA283	Sand/Gravel
42	Dutson	WA263	Limestone	123		WA40	Sand/Gravel
43		WA371	Sand/Gravel	124		WA157	Sand/Gravel
44	Longford	WA370	Limestone	125	Lang Lang	WA2	Sand/Gravel
45		WA449	Sand/Gravel	126	Lang Lang	WA333	Sand/Gravel
46		WA262	Sand/Gravel	127	Lang Lang	WA333	Sand/Gravel
47		WA262	Sand/Gravel	128	Lang Lang	WA333	Sand/Gravel
48		WA224	Sand/Gravel	129		WA2	Sand/Gravel
49		WA312	Sand/Gravel	130	Lang Lang	WA423	Sand/Gravel
50	Merrimans Creek	WA355	Limestone	131	Lang Lang	WA423	Sand/Gravel
51	Merrimans Creek	WA369	Limestone	132	Lang Lang	WA423	Sand/Gravel
52	Merrimans Creek	WA369	Limestone	133	Lang Lang	WA423	Sand/Gravel
53		WA447	Sand/Gravel	134		WA338	Sand/Gravel
54		WA261	Sand/Gravel	135		WA338	Sand/Gravel
55		WA261	Sand/Gravel	136		WA527	No longer current
56		WA447	Sand/Gravel	137		WA530	Sand/Gravel
57		WA171	Sand/Gravel	138		WA511	Sand/Gravel
58		WA447	Sand/Gravel	139		WA127	Sand/Gravel
59		WA171	Sand/Gravel	140		WA531	Sand/Gravel
60		WA280	No longer current	141		WA456	Sand/Gravel
61		WA280	No longer current	142		WA238	Sand/Gravel
62		WA280	No longer current	143	Tynong North	WA25	Granite
63		WA294	No longer current	144		WA182	Granite
64		WA317	Sand/Gravel	145		WA476	Sand/Gravel
65		WA405	Sand/Gravel	146		WA129	Sand/Gravel
66		WA89	Sedimentary	147		WA189	Hornfels
67		WA298	Sand/Gravel	148		WA128	Basalt Old
68		WA112	Clay/Clayshale	149		WA128	Basalt Old
69		WA64	Clay/Clayshale	150		WA128	Basalt Old
70		WA455	Sand/Gravel	151		WA128	Basalt Old
71		WA162	Sand/Gravel	152		WA237	Basalt Old
72		WA162	Sand/Gravel	153	Yarragon	WA462	Peat
73		WA19	Sand/Gravel	154		WA406	Sand/Gravel
74		WA281	Sand/Gravel	155		WA521	Sand/Gravel
75		WA293	Basalt Old	156		WA523	Sand/Gravel
76	Jeeralang North	WA168	Basalt New	157		WA204	Sand/Gravel
77		WA168	Basalt New	158		WA103	Sand/Gravel

Map 2 locn	Name	Work authority number	Commodity	Map 2 locn	Name	Work authority number	Commodity
78		WA119	Sand/Gravel	159		WA23	Sand/Gravel
79		WA354	Sand/Gravel	160		WA454	Sand/Gravel
80		WA284	Sand/Gravel	161	Rocky Camp (Buchan)	WA197	Limestone
81		WA499	Sand/Gravel	162	Nowa Nowa	WA86	Rhyodacite
82		WA368	Sand/Gravel	163		WA357	Limestone
83		WA206	Sand/Gravel	164		WA126	Limestone

Basalt for road making, building and concreting has been quarried from Older Volcanics at Yallourn North, Jeeralang North, Ruby, Dumbalk North and Leongatha South. Sandstone for road building is quarried from a number of localities with large quarries near Jerralang Junction, Mount Speed and Trafalgar (Douglas 1984).

Limestone and sandstone used for agriculture and aggregate is extracted from the Seaspray and Sale Groups, east of Bairnsdale.

Sand and gravel pits operated by the former Department of Conservation and Natural Resources are an important local source of road surfacing material (Maher *et al.* 1996). The Haunted Hill Gravel is the principal source of sand and gravel in the south-west of the region and it is used in roads, housing, concreting and pipe manufacture (Douglas 1984). Major potential construction sand resource areas are at Trafalgar and in land overlying the brown coal basins in the Latrobe Valley in the southwest corner of the region (McHaffie & Buckley 1995, Bowen 1988a).

Erosion of Cretaceous/Tertiary clays formed alluvial clay deposits later in the Tertiary and Quaternary ages and extensive deposits are associated with brown coal at Morwell (McHaffie & Buckley 1995).

Soft, weathered siltstone from the Boola Formation is used to make bricks at Morwell and clay derived from basalt is also quarried at Tyers for bricks. There is another clay pit at Hallora in the Childers Formation (Douglas 1984).

Dimension stone

The Gippsland region has a number of potential sources of dimension stone of various types (Map 2) and the main localities for dimension stone are as follows:

Locality	Type
Bindi	Marble
Limestone Creek	Marble
Colquhoun	Granite
Mount Taylor	Granite
The Brothers	Granite

Silurian age marble at Bindi features an attractive strong fabric accentuated by shades of cream, pink and grey but local jointing may affect its marketability (Maher *et al.* 1996).

Marbles in the Limestone Creek, Stoney Creek and Clare Creek areas display a wide range of attractive colours, mostly veined and mottled on cream, white and grey bases. Marble lenses occupy areas exceeding 12 hectares and contain large quantities of massive marble. There is a small disused marble quarry at Limestone Creek, where cream and grey banding is evident. This limestone has good characteristics for use as monumental and dimension stone, although its extraction is limited by the bulk of its outcrop occurring within the Cobberas-Tingaringy National Park (King & Weston 1997).

The Colquhoun Granite has been used for monumental purposes and is fine grained, uniform in texture and composition with a pink to red colour. Large portions are covered by Tertiary sediments but it could be suitable as a dimension stone resource depending on the amount of overburden and land use status. The Mount Taylor Granite is medium grey, strongly porphyritic (large crystals) granite that is also partially covered by Tertiary sediments (Maher *et al.* 1996).

Syenite outcropping on the southern slopes of The Brothers consists of a coarse-grained, pale brown rock with pale blue schiller in large feldspars. It contains occasional xenoliths and jointing is well spaced. Although this rock has not been previously used as dimension stone, its texture and favourable jointing make it a potential source (Maher *et al.* 1996).

Devonian-Carboniferous sandstones in the Macalister, Avon and Mitchell River Basins constitute potential sources for dimension stone. The sandstone at Briagolong has been used for local buildings and show no significant deterioration even after 105 years of exposure in local buildings (King & Weston 1997). An Extractive Industry Work Authority has been granted for quarrying micaceous lithic sandstones in the Valencia Creek-Avon River area. The Devonian-Carboniferous basins are largely unexplored for dimension stone and the range of colour and the durable nature of these sandstones indicate a potential for quality dimensional sandstone.

Kaolin

A secondary kaolinitic clay deposit below the mid-Tertiary age Morwell No 1 brown coal seam in the Morwell open cut mine is up to 10 metres thick and contains some grit and organic matter. A pit in the floor of the open cut is periodically used to extract this clay for making white ware. The upper six metres of overburden clay on the northern side of the open cut have been used to make wall tiles but the material is now inaccessible. At nearby Yallourn, a similar, but less pure, secondary kaolinitic clay layer lies under the brown coal open cut (McHaffie & Buckley 1995). Similar clay seams are likely to occur in the brown coal bearing Moe Swamp Basin.

At Heyfield white kaolinitic clay occurs as two seams interbedded with early Tertiary age sand and gravel. This clay has been worked for the ceramic and chemical industries (VandenBerg 1977). Further east a 10 metre thick kaolinitic clay sequence occurs which may be suitable for ceramics (McHaffie & Buckley 1995).

Bauxite

A cluster of deposits south-west of Morwell are the only known deposits with economic significance in Victoria. There are about 40 bauxite occurrences in this area and about half have been identified as small residual deposits formed by deep weathering of basalt and tuffaceous volcanics (McHaffie & Buckley 1995). Estimated initial resources of the two largest deposits were about 200 000 tonnes of bauxite each and the other deposits contained less than 50 000 tonnes. Most of these resources have been worked out (Nott 1988, cited in McHaffie & Buckley 1995).

Bauxite mining for production of aluminium salts began in Victoria in 1919 near Thorpdale. A little further south, Geelong Cement and Asko Chemicals mined bauxite until 1992 from the Paynes and Watkins deposits for use as an additive in cement manufacture. Total recorded bauxite production for Victoria since 1926 is about 200 000 tonnes and in 1991–92 was about 5 000 tonnes (McHaffie & Buckley 1995). Resources at the Watkins and Paynes deposits are sufficient for many years at past production rates, and Geelong Cement has

found significant new resources near Paynes. At Watkins there is a substantial resource of high alumina clay beneath the bauxite (Nott 1988, cited in McHaffie & Buckley 1995).

Feldspar

Significant occurrences of feldspar are located at Pyles and The Brothers. The feldspar at Pyles is hosted by dykes whereas The Brothers deposit is a Triassic syenite. Mount Taylor is another feldspar occurrence. Analysis of feldspar bearing tinguaites and phonolite dykes and plugs at Mount Smythe (just northwest of the region) showed the rock, after beneficiation, had low iron and high alkali content and could be of economic value (McHaffie & Buckley 1995). Such dykes and plugs may also occur in the region.

Precious and semi-precious stones

A number of occurrences are scattered through the region and are listed in Table 11.

Table 11 Precious and semi-precious stones sites

Location	Commodity	Source
Avon River	Jasper	McHaffie and Buckley (1995), Birch and Henry (1997)
Toora	Agate, chert, jasper, quartz, ruby, sapphire, topaz and zircon	McHaffie and Buckley (1995), Birch and Henry (1997)
W-tree/Gelantipy	Common (opaque to translucent) opal	McHaffie and Buckley (1995)
Cape Liptrap & Walkerville	Jasper, serpentinite and green nickeliferous quartz	Stone 1967 (cited in Douglas 1984)
Yanakie	Garnet, zircon, green and blue sapphire, topaz, and almandine ruby	Stone 1967 (cited in Douglas 1984)
Wilsons Promontory	Tourmaline	Stone 1967 (cited in Douglas 1984)

Phosphate

Phosphate occurs in the Hoddle Range in the south of the region where it is hosted by intraformational breccia of Ordovician age. An analysis of 19.7 per cent P_2O_5 is recorded but grades are usually low and quantities are small (Cooney 1967, cited in Douglas 1984). Cambrian age tuffaceous sediments also contain phosphate at Fullarton Spur, north of Licola (McHaffie & Buckley 1995).

Barite

Barite has been recorded at Gibbo River (Oppy *et al.* 1995).

Most of Victoria's known barite deposits occur east of Bairnsdale and are east of the region. The major deposits are Bally Hooly Hill, Kanni Creek and Iron Mask, and all are associated with the Snowy River Volcanics (Maher *et al.* 1996). Similar host rocks occur in the region.

Wollastonite

Wollastonite occurs at Morass Creek and Pyles.

Pyrophyllite

Pyrophyllite is recorded from the Wilga deposit, and the Pyramid Mountain and Blue Spur prospects (Maher *et al.* 1996).

Talc

At Bingo Munjie North, talc occurs in altered basic dykes in red granite (Bartlett & Learmonth 1955, cited in Maher *et al.* 1996). Talc production of 83 tonnes during 1948–49 came from the crushed and faulted margins of a Cambrian greenstone (diabase rock type) in the Howqua Hills, just northwest of the region (Bowen 1988b). These host rocks extend into the region.

Potential mineral and extractive resources

Mineral potential assessment methodology

A qualitative assessment of the potential resources of an area is an estimate of the likelihood of occurrence of mineral deposits, which may be of sufficient size and grade to constitute a mineral resource. The term ‘mineral resource’ is restricted to material, the extraction of which is judged to be potentially viable, either now or within the next 25 years. Only the deposit types judged to be most likely to constitute significant resources in the region have been assessed in detail.

The mineral potential of the Gippsland region has been assessed by determining the types of mineral deposits likely to be found within the geological framework known or believed to exist there. This approach identifies geological units (tracts) which could contain particular types of mineral deposits. The general methodology used was developed by the United States Geological Survey (USGS), and has been used successfully for mineral resource assessments of wilderness areas in North America and elsewhere. A summary of the qualitative assessment methodology is described in publications by Marsh *et al.* (1984), Taylor and Steven (1983), and by Dewitt *et al.* (1986).

An assessment of a region’s potential mineral resources combines knowledge of its geology, geophysics, geochemistry, mineral deposits and occurrences with current theories of mineral deposit genesis and results of mineral exploration. The assessment uses available geoscientific data to determine the history of geologic processes and environments. Geologic environments judged to have characteristics known to be associated with specific types of mineral deposits are then identified. In particular, the assessment draws on regional and local characteristics of mineral deposit models to establish whether or not specific types of deposits are likely to occur.

The mineral potential of an area – that is, the likelihood of a particular type of mineral deposit occurring – is ranked as ‘high’, ‘moderate’, ‘low’ or (where there is insufficient data) ‘unknown’. To reflect the differing amounts of information available, the assessments of mineral potential are ranked from A-D according to levels of certainty, ‘A’ denoting the lowest level of certainty and ‘D’ the highest (Figure 1). The method is described in more detail in Appendix A.

Assessments similar to the procedure used here in this report for the Gippsland region are commonly used by companies to select areas for exploration. It is important to note, however, that the assessment of potential resources is subject to the amount and the quality of data available to the assessors. As geological knowledge of an area can never be complete, it is not possible to have a ‘final’ assessment of potential mineral resources at any given time. Mineral resource potential needs to be monitored and periodically reassessed to take account of new data and advances in geological understanding, including new mineral discoveries. Advances in mineral exploration and mining technologies and market changes may also change the mineral resource potential of an area.

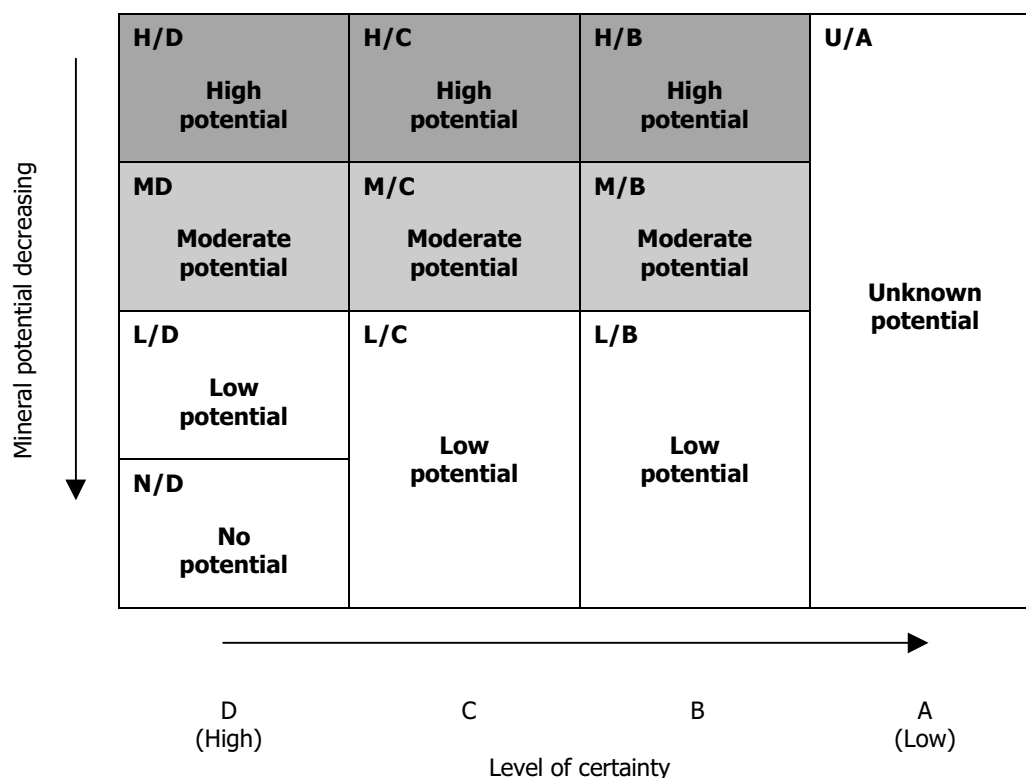


Figure 1 Relationship between levels of resource potential and levels of certainty

Due to incomplete geological knowledge, the discovery rate in Australia is roughly of the order of one mine for one thousand exploration programs. Thus areas are explored, often repeatedly, before a mineral deposit is found. Increased geological knowledge and other factors can result in discoveries of world class deposits both in highly prospective areas (e.g. Kanowna Belle in Yilgarn, WA; Century in the Mount Isa Inlier, Qld) or in areas not previously known to be of very high potential (e.g. Olympic Dam on Stuart Shelf, SA). Thus continued access to land for regulated exploration, which is a transient process rather than a long-term land use, is an important issue for the minerals industry and for future mineral development.

Geological areas (or ‘tracts’) in the Gippsland region, judged to contain geological environments permissive of the formation of specific types of mineral deposits have been delineated and their mineral potential ranked (Figures 3 to 23).

Mineral and extractive potential in the Gippsland region

Descriptive mineral deposit models used for qualitative broadscale assessment of the Gippsland region are described in Appendix B. The favourable geological tracts for these types of mineralisation are indicated on Figures 3 to 23. The potential mineral resources are summarised in Table 12 and are described below as follows.

Table 12 Summary of potential mineral resources at April 1999

Deposit type	Mineral potential	Certainty level	Area of tract (sq km)	% of region covered by tract	% of tract in exempt Crown land*
Slate belt gold	High	B-C	6 990	26.40	16.4
	Moderate-high	B	4 258	16.10	35.4
	Moderate	B	89	0.30	0.0
	Low-moderate	B	134	0.50	2.2
Disseminated gold	Moderate-high	B-C	6 990	26.40	16.4
	Moderate	B	4 258	16.10	35.4
	Low-moderate	B	89	0.30	0.0
	Low	B	134	0.50	2.2
Epithermal gold–silver	High	B-C	253	1.00	1.4
	Moderate	B	428	1.60	5.1
Alluvial gold	Low-moderate	B-C	2 630	9.90	7.5
Porphyry copper-gold	Moderate-high	B-C	879	3.30	0.1
	Moderate	B-C	798	3.00	3.5
Volcanic associated massive sulphide base metals	High	C	207	0.80	1.4
	Moderate-high	B	64	0.20	0.6
Volcanic associated massive sulphide gold	Moderate-high	C	207	0.80	1.4
	Moderate	B	64	0.20	0.6
Irish style	High	C	33	0.10	0.0
Tin veins	Moderate	B-C	908	3.40	13.4
	Low-moderate	B-C	57	0.20	0.0
	Unknown	A	11	0.00	0.0
Tin greisen	Low-moderate	B	5	0.00	0.0
	Low	B	267	1.00	5.1
	Unknown	A	11	0.00	0.0
Tungsten–molybdenum veins	Low-moderate	B	1 023	3.90	8.9
	Unknown	A	1 696	6.40	1.7
Tungsten skarn	Moderate	C	20	0.10	0.4
	Low-moderate	B	20	0.10	0.0
	Unknown	A	258	1.00	3.4
Nickel–copper deposits	Moderate-high	B	454	1.70	0.0
Sandstone uranium	Low-moderate	B-C	4 583	17.30	28.2
Sediment hosted copper	Moderate	B-C	2 203	8.30	27.5
Brown coal	High	D	1 092	4.10	1.4
	Moderate-high	C	5 539	20.90	1.9
Dimension stone	High	C	204	0.80	0.5
	Moderate-high	B	2 290	8.60	29.7
	Moderate	C	0.2	<0.1	0.0
	Low	B-C	448	1.70	0.0
Limestone	High	C	124	0.50	2.1
	Moderate-high	B	17	0.10	0.0
	Moderate	B	192	0.70	0.2
Silica sand	High	C	147	0.60	0.0
	Moderate	B	2 015	7.60	2.3
	Low	B	353	1.30	2.1
Kaolin	High	C-D	107	0.40	0.0
	Moderate	B	1 032	3.90	1.4
	Low	C	1 488	5.60	1.2
Bauxite	Moderate	C	520	2.00	0.0

* Exempt Crown land in this column comprises National and State Parks Wilderness and Reference Areas

Gold

Slate belt gold deposits (Figure 3)

Tract Au1a/H/B-C—The tract is delineated based on structural corridors around the Kiewa Fault, which hosts bulk of the known slate-belt gold occurrences in the region; and the Woods Point dyke swarm that hosts the Walhalla – Woods Point gold subprovince. The fault zones in both of these corridors are known to have played a role in controlling gold mineralisation. The corridors contain:

- Turbidites of Ordovician to Devonian age and their metamorphic equivalents;
- Dyke swarms (Woods Point; possible extensions of Mitta-Mitta, and Tintaldra-Cudgewa, Walwa, and other smaller dyke swarms in the Benambra gold province); and
- Silurian and Devonian granites within a corridor defined by the Wonnangatta Fault in the west and the Ensay Fault in the east.

The tract contains most of the known primary gold occurrences and a large number of alluvial deposits.

The mineral potential of the tract is assessed as high with a certainty level of C in areas of known dyke swarms and a certainty level of B for area where dykes are interpreted based on the high resolution aeromagnetics.

Tract Au1b/M-H/B—The tract includes areas that contain the favourable host rocks described in the preceding tract but located outside the two structural corridors. The tract is known to host several primary and placer gold occurrences.

Mineral potential of the tract is assessed to be moderate to high with a certainty level of B.

Tract Au1c/M/B—The tract includes windows of Ordovician (Mount Easton Shales), Silurian and Devonian sedimentary rocks in the southern part of the Latrobe Valley. These are favourable host rocks for the mineralisation and host a few occurrences of slate belt gold. The tract is assigned moderate potential (certainty level of B) because strike direction of major faults in the tract is north east, which is different from the meridional and northwest direction in the three major gold provinces in the area. In addition known outcrops of Silurian and Devonian granitoids are more than 15 kilometres away.

Tract Au1d/L-M/B—The tract contains area occupied by Silurian I and S-type granitoids outside the structural corridor. The granitoids contain a few occurrences of slate belt gold. In the Benambra gold province some granitoids are intruded by dykes. Granitoids often host some slate belt gold mineralisation but they are not as good hosts as turbidites.

Mineral potential of the tract is thus assessed to be low to moderate with a certainty level of B.

Disseminated gold deposits (Figure 4)

Tract Au2a/M-H/B-C—This tract is identical to the high potential tract (tract Au1a/H/B-C) for slate belt gold deposits and contains the most favourable environment for the emplacement of slate-belt gold mineralisation as outlined under the previous section for slate-belt gold. The presence of slate belt gold occurrences and the fact that it has a high potential for the presence of more deposits of this type indicates that the tract has a potential for disseminated gold deposits.

Mineral potential for disseminated gold deposits in the tract is assessed to be moderate to high with a certainty level of B to C.

Tract Au2b/M/B—The tract is identical to the Au1b/M-H/B tract for slate belt gold deposits. It includes areas that contain favourable host rocks described in the preceding tract but located outside the two structural corridors. The tract is known to host several primary and placer gold occurrences.

Mineral potential of the tract is assessed to be moderate potential with a certainty level of B.

Tract Au2c/L-M/B—The tract is identical to the moderate potential tract (tract Au1c/M/B) for slate belt gold deposits. It includes windows of Ordovician, Silurian and Devonian rocks in the southern part of the Latrobe Valley. Hence mineral potential of this tract is assessed to be low to moderate with a certainty level of B.

Tract Au2d/L/B—The tract is identical to the low to moderate potential tract (Au1d/L-M/B) for slate-belt gold deposits. Main rocks in the tract are Silurian and Devonian granitoids which are known to host several occurrence of primary slate-belt gold. The potential for slate-belt gold in the tract has been assessed to be low to moderate. Deposits of disseminated gold may be associated with the slate belt gold and on the available evidence the tract has a low potential for disseminated gold deposits with a certainty level of B.

Epithermal gold-silver deposits (Figure 5)

Tract Au3a/H/B-C—The tract contains areas favourable for two types of epithermal gold-silver deposits. One of them is defined by Cambrian volcanics that form the north-northwest trending Barkly River Greenstone Belt in the western part of the Gippsland region. The tract includes small areas where the presence of greenstone rocks is deduced from the interpretation high-resolution aeromagnetics. The belt hosts a number of known occurrences which have features similar to epithermal gold-silver deposits (Turner 1996).

The second type of epithermal gold-silver deposits is related to the volcanic, volcanoclastic and sedimentary rocks of the Snowy River Volcanics, exposed mainly within the Buchan Rift. The tract also includes the Mount Elizabeth caldera that contains rocks of the Snowy River Volcanics and Devonian granodioritic bodies.

Thus based on the available information it is concluded that the tract has a high potential for epithermal mineralisation with a certainty level of C. Areas within the interpreted boundary of the caldera are assigned a lower level of certainty (B).

Generally epithermal systems which form quartz-adularia type of mineralisation also generate acid-sulphate type of gold-silver mineralisation. This mineralisation is usually confined to the uppermost parts of the system. Hence it is possible that locally the tract contains this type of mineralisation.

Tract: Au3b/M/B—Devonian S-type subaerial felsic volcanics and volcanoclastics such as the Sheevers Spur Rhyodacite.

The tract is interpreted to have a moderate potential for epithermal gold-silver deposits with a certainty level of B.

Alluvial gold deposits (Figure 6)

Tract Au4a/L-M/B-C—Distribution of Tertiary and Quaternary sediments has been used to delineate this tract. In the Gippsland Basin, Tertiary and Quaternary rocks that are in the marginal part of the basin (within five kilometres of the basin boundary) are included.

The tract hosts numerous slate-belt gold and disseminated gold deposits/occurrences which are potential sources of alluvial gold. The tract contains numerous occurrences of alluvial gold.

It is concluded that the tract has a low to moderate potential (with a certainty level of C for the tract outside the basin and B for the tract within the basin) for alluvial gold.

Base metals

Porphyry Copper-gold deposits (Figure 7)

Tract CuAu1a/M-H/B-C—The tract includes Silurian and Devonian I and S- type granitoids and the surrounding country rocks in the eastern part of the Gippsland region. All granites have strong to moderate magnetic response on high resolution aeromagnetics. The surrounding country rocks (Ordovician turbidites) are included in the tract because high resolution aeromagnetics suggests that magnetic granitoids are present at shallow depths under these rocks. The granitoids included in the tract are: Case Granite, Colquhoun Granite, Kenny Creek Granite, Mellick Munjie Granodiorite, Mollys Plain Granite, Mount McLeod Granodiorite, Nunniong Granodiorite, Saint Patricks Creek Granite and Tambo Crossing Granite.

The tract contains several copper, copper-molybdenum, copper-molybdenum-gold and copper-gold prospects with features similar to copper porphyry systems.

Based on the above information the tract is assessed to have moderate to high potential for porphyry copper deposits with a certainty level of C. Lower levels of certainty (B) are assigned to areas that have been included based on aeromagnetic anomalies.

Tract: CuAu1b/M/B-C—The tract includes Early Silurian and Devonian I-type, mainly mafic granitoids with a high aeromagnetic response indicative of their possible oxidised state. The granitoids included in the tract are: Anglers Rest Granite, Angora (Old Sheep Station) Granite, Barry Mountains intrusive, Castlebum, Dargo, Ensay Tonalite, Eumana (Reedy Flat) Granite, Mount Baldhead, Mount Selwyn Granite, Rileys Creek Granite and Tongio Gap Granite. Included in the tracts are two unnamed I-type Silurian granites and one Early Devonian I-type granite. The tract also includes areas adjacent to the outcropping granitoids where aeromagnetics suggest their subsurface extensions at shallow depths.

Alkaline igneous rocks of the Triassic Mount Leinster Igneous Complex are also included in the tract as similar alkaline rocks in Tasmania and New South Wales are reported to host gold mineralisation.

Although the geological criteria are favourable, porphyry type mineral occurrences have not been located within this tract to date.

The potential is assessed to be moderate with a certainty level of C. Lower levels of certainty (B) are assigned to areas where the presence of granite is delineated using aeromagnetics.

Copper porphyry systems often generate hydrothermal activity, which is capable of forming several types of associated deposits. Most common of these are: base-metal skarn, copper skarn, epithermal veins, polymetallic replacement, and volcanic hosted massive replacement deposits.

Volcanic associated massive sulphide deposits (VMS) (Figure 8)

Tract: BM1a/H/C—This tract delineates areas of Cambrian metabasalts, gabbro and sediments that have potential for volcanogenic base metal deposits. The Cambrian Mt Wellington greenstone belt in the Gippsland region has several known base metal occurrences and prospects are currently being explored in the greenstone belt. Base metal and precious metal mineralisation of this type is known to occur in the North East Victoria RFA region. Some of these rocks are geochemically similar to the Cambrian Mount Read Volcanics of western Tasmania, which host major VMS base metal deposits (Crawford 1988).

The tract also includes marine volcanic and volcanoclastic rocks of the Gibsons Folly Formation which host the two significant deposits (Wilga and Currawong) in the Limestone Creek Graben. Undiscovered mineral deposits could also be hosted in rocks underlying the Gibsons Folly Formation (Cowombat Siltstone, Thorkidaan Volcanics and the Towonga Sandstone) in the Limestone Creek Graben and in the Reedy Creek Outlier.

The tract is assessed to have a high potential for volcanogenic massive sulphide deposits, with a certainty level of C.

Tract BM1b/M-H/B—The tract includes central and southern parts of the Buchan Rift where the volcanoclastics of the upper member of the Snowy River Volcanics, and the basal unit of the Buchan Caves Limestone frequently contain base metal mineralisation of volcanic exhalative origin. Mineral prospects of this type include the Shaw's Gully, Blue Bullocks Creek and Hackett Creek prospects and New Guinea lead occurrences. Detrital sphalerite and galena together with enriched manganese, barium and silver values with waterlain tuffs, pyritic shales and intraformational breccias point at the volcanic massive sulphide nature of mineralisation in these prospects.

The tract also includes the Mitta Mitta Volcanics, the overlying Wombat Creek Group and the Dartella Volcanic Group in the Wombat Creek Graben. Known mineralisation in these rocks is confined to some minor base metal occurrences in the Wombat Creek Group and some signs of exhalative mineralisation in the Dartella Group. It is possible the volcanoclastic-sedimentary rocks of the Wombat Creek Group host a second horizon of volcanic massive sulphide deposits below the Gibsons Folly Formation. It is also possible that these older rocks contain disseminated stockwork style mineralisation, often present below massive sulphide bodies in VMS deposits.

Potential for volcanic hosted massive sulphide deposits in the tract is considered to be moderate to high with a certainty level of B.

Gold associated with volcanic massive sulphide mineralisation (Figure 9)

Volcanic hosted massive sulphide deposits are often associated with significant gold mineralisation. Many massive sulphide deposits in Tasmania such as Que River and Hellyer belong to this category. Volcanic-hosted massive sulphide deposits in the Captains Flat-Goulburn and the Hill End Synclinal zones also contain gold and silver mineralisation. Mineral occurrences in the Jamieson Window of Cambrian volcanic and volcanoclastic rocks have been reported to return gold values.

Tract: Au5a/M-H/C—This tract coincides with the tract BM1a/H/C for volcanic associated massive sulphide deposits. The tract contains several occurrences of base metals with gold values. The tract contains Silurian submarine volcanic rocks that host massive sulphide deposits of Wilga and Currawong near Benambra located in the Limestone Creek Graben. These deposits are known to have up to 1.3 grams per tonne gold (Allen and Barr 1990).

The likelihood of gold mineralisation associated with volcanic massive sulphide depends on the presence of volcanic massive sulphide deposits and not all massive sulphide deposits have significant gold mineralisation. The potential of this tract for gold mineralisation is therefore assessed to be of a level lower than that of volcanic associated massive sulphide deposits. Hence the potential of the tract is assessed as being moderate to high with a certainty level of C.

Tract: Au5b/M/B—This tract coincides with the BM1b/M-H/B tract for volcanic associated massive sulphide deposits. The tract includes central and southern parts of the Buchan Rift

where the volcanoclastics of the upper member of the Snowy River Volcanics, and the basal unit of the Buchan Caves Limestone frequently contain base metal mineralisation of volcanic exhalative origin. The tract also includes the Mitta Mitta Volcanics, the overlying Wombat Creek Group and the Dartella Volcanic Group in the Wombat Creek Graben.

For reasons similar to those outlined in the above tract, the potential of this tract is assessed to be moderate with a certainty level of B.

Irish-style carbonate hosted base metal deposits (Figure 10)

Tract BM2/H/C—This tract is delineated based on the distribution of rocks belonging to the Buchan Group within the Buchan and Bindi rifts.

The Buchan Caves Limestone, which is the lowest member of the Buchan Group is thought to have formed in a shallow marine environment (shallow sloping carbonate shelf) after the initiation of marine transgression in the southern part of the Buchan Rift. There is some evidence that volcanism on a minor scale continued well after the onset of limestone deposition. The area contains several prospects that have features similar to the Irish-style base metal deposits.

Based on the available information it is concluded that the tract has a high potential for the Irish-style base metal deposits with a certainty level of C.

Tin vein deposits (Figure 11)

Tract Sn1a/M/B-C—This tract is based on the distribution of:

- Granitoids, which are felsic, fractionated, non-magnetic, S-type or I-type, and have tin vein deposits. These are the Nunniong Granodiorite and Anglers Rest Granite; and Silurian ‘fault rock’ granite to the northeast of Falls Creek. The Mount Singapore and Lilly Pilly Granites on Wilsons Promontory are associated with alluvial tin deposits; and
- Felsic dykes who are fractionated and have tin vein deposits. Aplitic dykes in an area to the northeast of Mount Pinnibar contain tin mineralisation. These are within the Surveyors Creek tinfield.

The tract includes a five kilometre buffer zone around the above granitoids and dykes

This tract is assessed as having moderate potential. The certainty level is C for areas where the presence of granite is clearly defined. The certainty level is B for the 5 km buffer around each granitoid and for areas where the granitoid is defined indirectly (e.g. presence of dykes).

Tract Sn1b/L-M/B-C—This tract is based on the distribution of felsic dykes and granitoids which are fractionated, non-magnetic, S or I-type, and for which there are no known occurrences of tin vein mineralisation. The Tynong Granite and Baw Baw Granodiorite are included in this tract.

The tract includes a five kilometre buffer zone around these granitoids and dykes.

This tract is assessed as having low to moderate potential. The certainty level is C for areas where the presence of granite is clearly defined. The certainty level is B for the five kilometre buffer around each granitoid and for areas where the granitoid is defined indirectly (e.g. presence of dykes).

Tract Sn1c/U/A—This tract is based on the distribution of non-magnetic granitoids which are classified as ‘Un’ (unknown) or ‘no information’ (Note: If the ‘Un’ granitoids are magnetic then these are considered to have no potential for tin veins). Devonian dykes to the west of Falls Creek; and the Sarsfield Granite are within this tract.

This tract is assessed as unknown potential with certainty level A.

Tin greisen deposits (Figure 12)

Tract Sn2a/L-M/B—This tract is based on the distribution of:

- Felsic dykes which are fractionated and have greisen tin deposits/prospects. This tract includes the southern extensions of the Mitta Mitta Dyke Swarm; and
- Granitoids which are S-type or I-type, felsic, fractionated, non-magnetic, and have greisen tin deposits/prospects. Greisenised dykes northeast of Mount Pinnibar and Silurian ‘fault rock’ granitoid northeast of Falls Creek are included in this tract.

This tract is assessed as low to moderate potential with certainty level B.

Tract Sn2b/L/B—This tract is based on the distribution of Granitoids which are S-type or I-type, felsic, fractionated, non-magnetic, and for which there are no known occurrences of greisen tin mineralisation. These include Anglers Rest Granite, the Baw Baw Granodiorite, the Tynong Granite and the Mt Singapore and Lilly Pilly Granites.

This tract is assessed as low potential with certainty level B.

Tract Sn2c/U/A—This tract is based on the distribution of Granitoids which are classified as ‘Un’ (unknown) or no information on the map of granites and related rocks of the Lachlan Fold Belt prepared by Chappell *et al.* (1991) and are non-magnetic. These include the Sarsfield Granite, Cobungra Granite, and an unnamed granitoid southwest of Falls Creek.

This tract is assessed as unknown potential with certainty level A.

Tungsten-Molybdenum vein deposits (Figure 13)

Tract WMo1a/L-M/B—This tract is based on the distribution of felsic dykes and granitoids, which are fractionated, moderately magnetic (moderately oxidised) and have W-Mo vein deposits/prospects. Silurian S-type granitoids are also included which are felsic, unfractionated, moderately magnetic and have W-Mo vein deposits (Mount Murphy wolfram mine). A five kilometre buffer zone around the above granitoids is included within the tract. The tract includes Tambo Crossing Tonolite, the Anglers Rest Granite, the Baw Baw Granodiorite, the Tynong Granite, the Buckwong Granodiorite and other Silurian granites east of Pinnibar and northeast of Falls Creek.

This tract is assessed as low to moderate potential with certainty level B.

Tract WMo1b/U/A—This tract includes all other granitoids about which the information is not sufficient to assess if they are fractionated, S or I type granites (e.g. Nunniong Granite).

This tract is assessed as unknown potential with certainty level A.

Tungsten skarn deposits (Figure 14)

Tract W1a/M/C—This tract contains the following lithological units:

- Pinnak Sandstone which hosts the Nowa Nowa magnetite skarn deposit;
- Seldom Seen Formation which hosts the Wulgulmerang wollastonite occurrence;
- Wombat Creek Group which hosts the Morass Creek wollastonite occurrence.

This tract is assessed as having a moderate potential with certainty level C.

Tract W1b/L-M/B—This tract consist of:

- five kilometre wide buffers adjacent to the margins of Palaeozoic granitoids, which are potential source rocks for tungsten mineralisation. The buffers are restricted to granitoids which are S-type or I-type felsic, fractionated, moderately magnetic (moderately oxidised) and have W-Mo vein deposits/prospects. The tract also includes Silurian S-type granitoids which are felsic, unfractionated, moderately magnetic and have W-Mo vein deposits (Mount Murphy wolfram mine); and
- Palaeozoic limestones and dolomites which were intruded by these granitoids.

The intersection of these calcareous rocks with the 5 km buffer zone around the granitoids defines the tract for tungsten skarn mineralisation. This tract is assessed as having low to moderate potential with certainty level B.

Tract W1c/U/A—This tract is the intersection of calcareous rocks with the 5 km buffer zone around those granitoids which have an unknown potential for W-Mo mineralisation. These granites are the same as those for the tungsten-molybdenum tract WMo1b/U/A.

This tract is assessed as unknown potential with certainty level A.

Nickel copper deposits (Figure 15)

Tract: NiCu/M-H/B—The tract includes the Woods Point Dyke Swarm and the surrounding Devonian (meta) sedimentary country rocks (Walhalla Group, Montys Hutt Formation and Norton Gully Sandstone). These rocks have the potential to host small copper nickel deposits of the Thomson River type where thickenings or bulges in the dykes occur. The dykes contain mineralisation characteristic of this model type (synorogenic Ni-Cu) and hence the entire known outcrop area of the Woods Point Dyke Swarm is assessed as having moderate to high potential and it has a certainty level of B.

Sandstone type uranium deposits (Figure 16)

Tract: U1a/L-M/B-C—The tract for uranium deposits in the red beds is defined by the extent of the Macalister, Avon and Mitchell River Basins, and the Mount Tambo Group of sediments, all of which contain redbed sequences. Anomalous concentrations of uranium, sometimes associated with the copper occurrences have been recorded in them. Airborne uranium channel radiometric anomalies are generally low for the redbed sequences but can be locally high in the vicinity of some of the copper occurrences.

Secondary uranium mineralisation has been recorded within granitoids in the Ballarat-Bendigo zone and in the Omeo Zone (Bowen 1988c). Within the Melbourne Zone, the granitoids and volcanics have low uranium contents. These rocks may provide a source of uranium for deposition as sandstone type deposits.

The tract also includes the distribution of Lower Cretaceous Strzelecki Group sediments of the Gippsland Basin. The Lower Cretaceous sandstones of the Strzelecki Group were deposited in a reducing environment and unconformably overlie Palaeozoic basement

sediments and granitic rocks. The sediments contain carbonaceous plant material and interbedded coal layers (Douglas 1988) and are suitable host rocks for sandstone uranium deposits. Palaeochannels eroded into the basement would localise the inflow of oxidised groundwaters containing dissolved uranium. Uranium precipitation occurs at redox interfaces (roll-fronts) within the sandstone beds.

Devonian granitoids and volcanics within the Melbourne Zone contain low levels of uranium. These provide a possible source for the formation of sandstone uranium deposits. However, the potential for this type of deposit is reduced because of the low background levels of uranium in the granites.

On the available information the potential for sandstone uranium deposits is low to moderate with a certainty level of B to C. Lower levels of certainty (B) apply to areas occupied by Lower Cretaceous Strzelecki Group sediments.

Sediment hosted copper deposits (Figure 17)

Tracts: Cu1a/M/B-C—The tracts for sediment hosted copper and sandstone uranium are defined by the extent of the late Devonian redbed sequences in the Avon and Mitchell River Basins. Interfaces of reducing and oxidising environments in the redbeds together with structural traps in the basin and faults in the underlying basement rocks provide favourable settings for deposition of copper, silver and less frequently uranium from metal-bearing solutions. On the available evidence from exploration data, the redbeds in these basins are assigned a moderate potential for small deposits of copper with a certainty level of C.

The tract also includes the Macalister Basin and the Mount Tambo Group. Some copper occurrences have been recorded in the Macalister Basin but the extent of copper occurrences in the Mount Tambo Group is not known due to lack of exploration data. The Macalister Basin is also underexplored for these types of deposits. These redbed sequences are considered to have a moderate potential with a certainty level of B due to lack of exploration data.

Brown coal deposits (Figure 18)

Tract Bcoal/H/D—This tract has been delineated within the onshore Gippsland Basin. The tract consists of large areas of Late Tertiary and Quaternary sediments that overlie extensive coal seams. There is evidence from drilling that brown coal is widespread throughout the Tertiary sediments of the Gippsland Basin. The tract is based on geological parameters derived from drill hole and other data regarding the quality, depth and overburden ratio of brown coal seams. For regions where resources have a minimum seam thickness of 3 metres, an overburden:coal ratio of 2:1 or better, and a maximum depth of 300 metres, a mineral potential of high and a certainty level of D have been assigned.

Tract Bcoal/M-H/C—The tract includes the remainder of the onshore Gippsland Basin Tertiary sediments. There is evidence from drilling that brown coal is widespread throughout the Tertiary sediments of the Gippsland Basin. Where at least one of the three criteria (a minimum seam thickness of 3 metres, an overburden:coal ratio of 2:1 or better and a maximum depth of 300 metres) is not met, a mineral potential of moderate to high and a certainty level of C have been assigned.

Dimension stone deposits (Figure 19)

Tract Dimst1a/H/C—This tract includes the Devonian granitoids of the Colquhoun Granite and the Triassic trachytic and syenitic rocks of the Mount Leinster Igneous Complex. The

tract also includes the Devonian Buchan Caves Limestone and the Murrindal Limestone. These rocks host known quarries and occurrences of dimension stone.

On the available information these rocks in the tract are considered to have a high potential for dimension stone with a certainty level of C.

Tract Dimst1b/M-H/B—This tract is defined by the presence of Late Devonian-Carboniferous Snowy Plains Formation with sandstones in the MacAlister, Avon River and the Mitchell River Basins. The tract includes carbonate sequences with potential for dimension stone in the Silurian Cowombat Siltstone in the Limestone Creek Graben and the Wombat Creek Group.

The geological characteristics of these rocks and the presence of known occurrences and quarries indicates that these rocks have a moderate to high potential for dimension stone with a certainty level of B.

Tract Dimst1c/M/C—This tract is defined by Devonian Tynong Granite on the southwestern edge of the region. The Tynong Granite has been used previously as a dimension stone for the Shrine of Remembrance and to a lesser extent in some other buildings. This granite is well located on transport routes to Melbourne. The presence of some pyrite and jointing in the granite detracts from its potential as a dimension stone but the extensive area underlain by the granite is largely untested.

On the available information the Tynong Granite in this tract has a moderate potential for dimension stone with a certainty level of C.

Tract: Dimst1d/L/B-C—Lenses of crystalline limestone occur within the Norton Gully Sandstone and the Wurutwun Formation in the western part of the region. Limestones from these lenses have been extracted for ornamental purposes at Toongabbie and Griffiths quarries. The limestones of the Walhalla Group in the Tyers River – Coopers Creek area are also considered to have potential for dimension stone (King & Weston 1997).

The possible sources for dimension stone in this part of the region is limited to widely scattered lenses of crystalline limestone within the two formations and for this reason the potential over the whole of the tract is considered to be low. The certainty level is B and C.

Limestone deposits (Figure 20)

Tract Lst1a/H/C—This tract is defined by the Silurian-Devonian sedimentary rocks, which may contain limestones. The tract includes the Cowombat Siltstone, Wombat Creek Group, Buchan Caves Limestone and the Murrindal Limestone in the northeast of the region.

The tract includes extensive outcrops of limestone and is considered to have a high potential for limestone/dolomitic limestone deposits with a certainty level of C.

Tract Lst1b/M-H/B—This tract is delineated by the distribution of the Tertiary age Gippsland Limestone as exposed in drainage courses and includes a 100 metre buffer on stream courses downstream from the occurrences. Elsewhere the unit is extensively overlain by Tertiary sand and clay deposits.

The tract is considered to have moderate to high potential for limestone deposits with a certainty level of B.

Tract Lst1c/M/B—This tract is defined by other Devonian limestones in the southwestern part of the region and includes the Walhalla Group sediments which host the Tyers River, Coopers Creek, and Toongabbie quarries.

The tract is considered to have a moderate potential for limestone/dolomitic limestone deposits with a certainty level of B.

Silica sand deposits (Figure 21)

Tract: Silsnd1a/H/C—The tract defines Quaternary dune sands and the Tertiary Haunted Hills Formation sands being mined for silica sand at Lang Lang and also includes Tertiary deposits north of Yarram within the region. The tract is considered to have a high potential for silica sand with a certainty level of C.

Tract: Silsnd1b/M/B—This tract includes the Haunted Hills Formation in the southern part of the region that contains fluvial sediments where silica sand may be present. The tract is assessed to have a moderate potential for silica sand deposits with a certainty level of B.

Tract: Silsnd1b/L/B—The tract includes Quaternary coastal and inland dune sand deposits and swamp deposits. There is some possibility that silica sand deposits suitable for industrial use may be present. The tract is assessed to have a low potential for silica sand deposits with a certainty level of B.

Kaolin deposits (Figure 22)

Tract Kao1a/H/C-D—The tract is delineated by the extent of the coal seams within the mining leases in the vicinity of the Morwell and Yallourn open pit mining operations where secondary kaolin deposits are known to underlie the coal seams. The tract also includes a 2 kilometre buffer around the two known occurrences of kaolin at Heyfield and Boisdale.

The tract is considered to have a high potential for kaolin deposits with a certainty level of D in the vicinity of the Morwell and Yallourn operations and a level of C at Boisdale and Heyfield.

Tract Kao1b/M/B—The tract is delineated by the extent of the brown coal seams within the Gippsland Basin that have an overburden/coal ratio of 2:1 or less. The potential kaolin deposits underlying the coal seams within this tract is assessed as moderate with a certainty level of B.

Tract Kao1c/L/C—This tract is defined by the extent of the fluvial sediments of the Haunted Hills Formation that are known to contain secondary kaolin at Boisdale and other deposits of kaolin may be present elsewhere. The tract is considered to have a low mineral potential for kaolin deposits with a certainty level of C.

Bauxite deposits (Figure 23)

Tract: Bxt/M/C—This tract is delineated based on the distribution of Tertiary volcanics that include tholeiitic and minor alkaline basalts. Deep weathering of these can produce bauxite deposits. The tract also includes known bauxite occurrences and deposits. Based on the available information the potential of bauxite deposits is assessed to be moderate with a certainty level of C.

Construction materials

Higher value construction materials—The potential for economic deposits of higher value construction materials in the Gippsland region exists where suitable rock types, gravels sands

and clays occur within viable transport distances from population centres. The viable transport radius around a centre increases with population size because of the economies of scale of supplying a larger market and better road networks around larger centres. Deposits near good transport routes such as the Princes Highway and other major roads, with access to distant population centres may also be viable. Major population centres around which there would be a higher demand for construction materials include Warragul, Traralgon, Sale, Bairnsdale and Lakes Entrance.

Lower value construction materials—Most of the rock types in the Gippsland region have potential for lower value construction materials in their fresh or weathered state; and soil, sand and gravel are widespread across the region. Suitable materials are mainly used for secondary road building and extraction of material usually occurs in close proximity to these roads. The materials include: (1) rippable sandstone, shale, schist, weathered granite and other rock, (2) sand and gravel, (3) soil and clay.

Summary of potential for metalliferous and industrial minerals, and construction materials in the Gippsland region

Mineral potential tracts were identified for 15 types of mineral deposits and five types of industrial mineral deposits, and for brown coal.

The tracts of mineral potential for various types of mineral deposits (Figures 3 to 23) have been combined and summarised in two different ways in Maps 3 and 4. Extraction sites for low value construction materials are often dictated by other land uses such as real estate developments and by costs of transport and mineral potential for construction materials is not included in the combined mineral potential Maps 3 and 4.

Map 3 is a composite of mineral potential tracts over the Gippsland region and shows the highest level of mineral potential assessed (in December 1998) for any particular area in the region (Figures 3 to 23). Where tracts for different types of deposits overlap, this area is assigned the highest potential level of all the overlapping tracts. In this approach, the tract having the highest mineral potential in any particular area obscures tracts of lower mineral potential.

In terms of mineral potential, the region can be divided by a line running through Warragul and Bairnsdale, with the older Palaeozoic and Mesozoic rocks in the north and the younger Gippsland Basin to the south. The northern part of the region has extensive tracts of high and moderate to high potential for deposits of slate-belt gold and moderate to high potential for disseminated gold (Map 3, Figures 3 and 4). There are smaller tracts of high potential for epithermal gold deposits and volcanic associated massive sulphide base metal deposits in the central northwest of the region and in the north east of the region (Map 3, and Figures 5 and 8). Future discoveries of gold and other metalliferous deposits would most likely occur in the northern part of the region which also contains nearly all of the old goldfields. There is moderate to high potential for porphyry copper-gold along the eastern boundary of the region (Figure 7) and for nickel-copper along the western boundary north of Walhalla (Figure 15). There is also moderate potential for tin vein deposits northwest of Benambra and on Wilsons Promontory (Figure 11). Potential for other types of tin, tungsten and molybdenum deposits is primarily restricted to small tracts of low to moderate potential in the northern part of the region (Figures 12, 13 and 14).

Most of the southern part of the region is dominated by tracts of high and moderate to high potential for brown coal in the Gippsland Basin. All of the brown coal sequences with an overburden ratio of 2:1 are within the high potential tracts in this part of the region. There are less extensive tracts of high and moderate potential for silica sand, kaolin and moderate potential for bauxite.

Map 3 is a composite of mineral potential tracts for different types of mineral deposits that do not have equal economic values. For example, a tract with moderate to high potential for slate belt gold may be considered to have a higher economic value than a tract with moderate to high potential for dimension stone.

The mineral potential tracts in Figures 3 to 23 are superimposed on Map 4 to highlight areas with overlapping tracts. This presentation takes account of the diversity of mineral resource potential as well as the level of potential. This was done by allocating standard scores according to a subjective ranking of levels of mineral potential as follows: high potential (18), moderate/high (12), moderate (6), low/moderate (2), low (1), and unknown potential (no score). In those areas where tracts overlap, the scores are added and this cumulative score is assigned to overlapping areas. For example where there is an overlap of high potential for slate belt gold (score 18), moderate to high potential for disseminated gold (score 12), and moderate potential for limestone (score 6) then this area will have a cumulative potential score of 36.

It should be understood that the areas with overlapping tracts highlighted by Map 4 emphasise the diversity of deposit types and their mineral potential, but these areas are not necessarily always more prospective than a single tract of high potential, e.g. slate-belt gold. As with Map 3, the relative economic potential of different deposit types has not been accounted for. The relative economic significance of the tracts for different types of mineral deposits, as perceived by mining companies, would be influenced by their perceptions of prospectivity, commodity prices, future market conditions, land access and other factors.

In the northern part of the region (Map 4) the areas with the higher cumulative mineral potential scores occur in the north-east and along the western boundary of the region. In the north-east of the region, elevated cumulative scores are present in the Wombat Creek Graben area, the Limestone Creek Graben and in the area adjacent to the Buchan Rift. In the Wombat Creek Graben area there are overlapping tracts for 10 different types of deposits including gold, base metals and industrial minerals with a cumulative score of up to 64. (Map 4, Figures 3, 4, 6, 8, 9, 11, 13, 14, 19 and 20). In the Limestone Creek Graben area there is potential for eight different types of deposits for gold, base metals and industrial minerals with a cumulative score of 48 (Map 4, Figures 3, 4, 5, 8, 9, 14, 19, and 20). This part of the region includes the base metal deposits of Wilga and Currawong. In the nearby Bindi Creek Graben the cumulative score reaches 114 from seven overlapping tracts and includes tracts for five types of deposits having high potential for gold, base metals limestone and dimension stone. In the area adjacent to the Buchan Rift in the south-east there are partly overlapping tracts for seven different types of deposits giving a cumulative score of 60 (Map 4, Figures 3, 4, 5, 7, 8, 9, and 13). On the western boundary of the region, north and south of Walhalla, there is a partial overlap of mineral potential tracts for nine types of deposits for gold, base metals, industrial minerals and coal. South of Walhalla the cumulative score reaches a maximum of 64 where tracts of mineral potential for eight types of mineral deposits overlap including gold, base metals and industrial minerals (Map 4, Figures 3, 4, 6, 15, 18, 19, 21, and 22).

In the Gippsland Basin, in the southern part of the region, the maximum cumulative score reaches 42 to 44 in scattered small areas where there are overlapping tracts for brown coal and three types of industrial minerals (Map 4, Figures 18, 20, 21, and 22). This part of the

region illustrates the differences in presentation of mineral potential between Maps 3 and Map 4. Although the brown coal deposits are very important, and show up as areas of high mineral potential on Map 3, there is potential for only a few other types of deposits in these areas and hence the relatively lower cumulative score reflects the low diversity of potential in these areas.

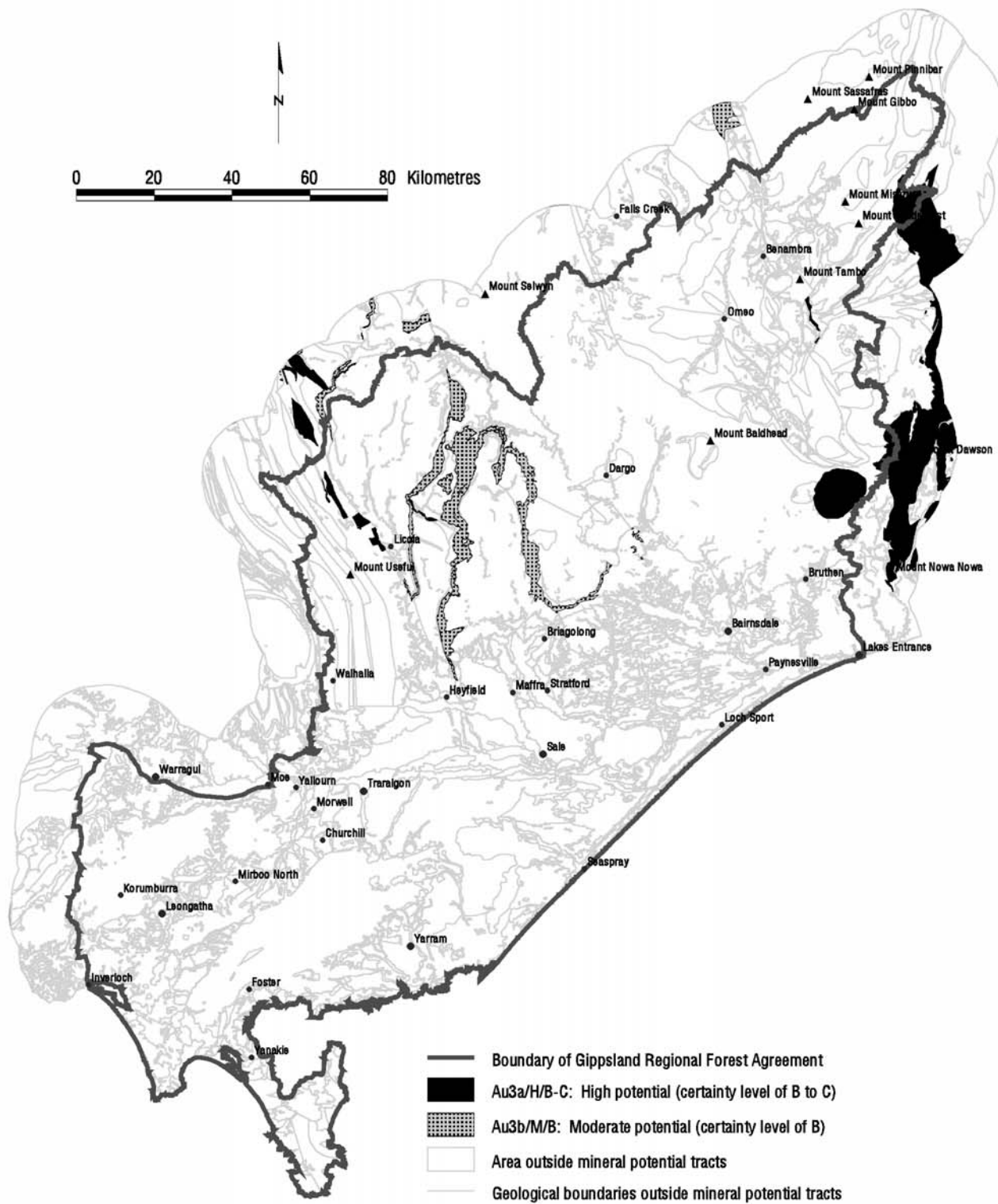


Figure 5 Mineral potential tracts for epithermal deposits for gold and silver

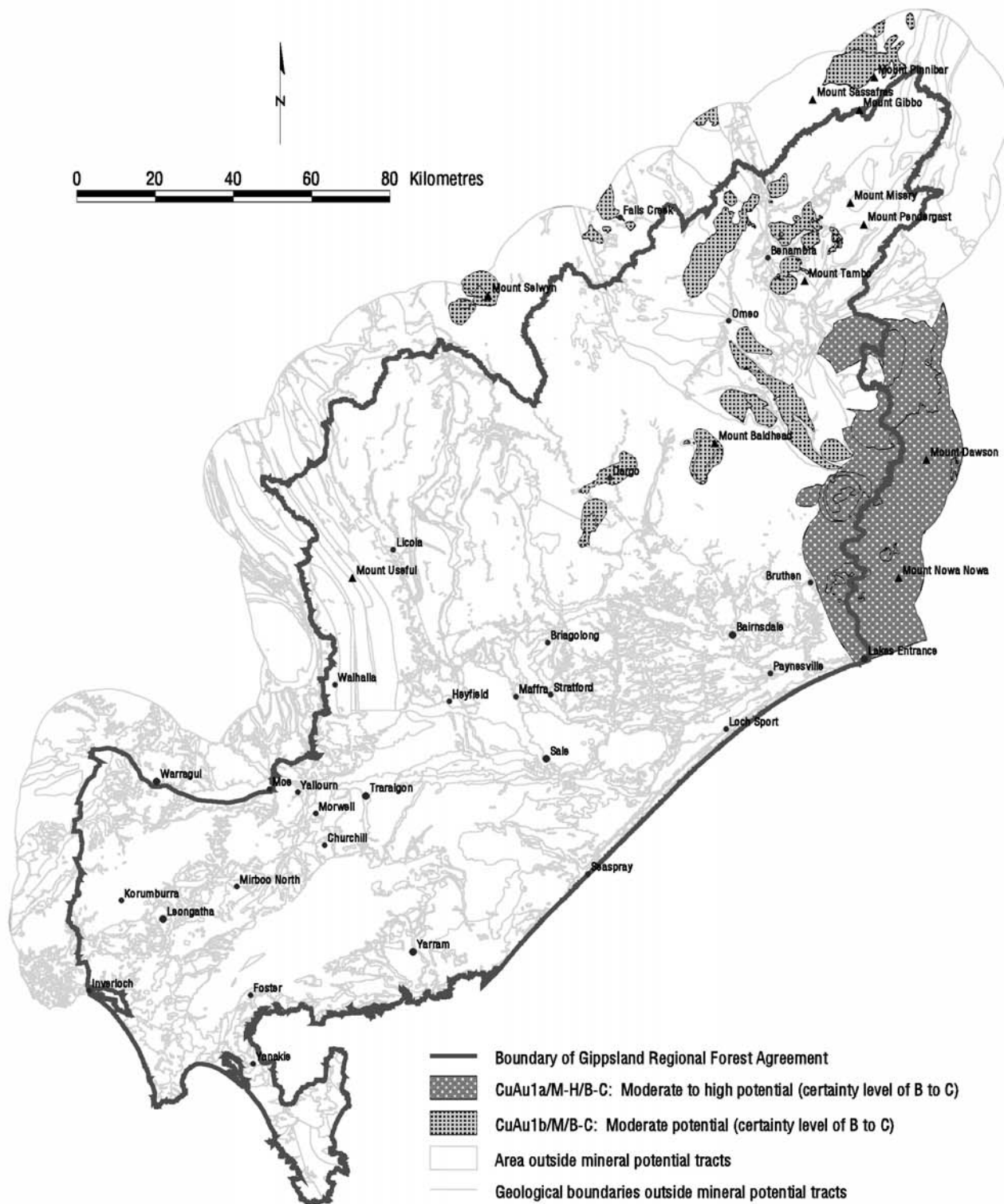


Figure 7 Mineral potential tracts for porphyry copper-gold deposits

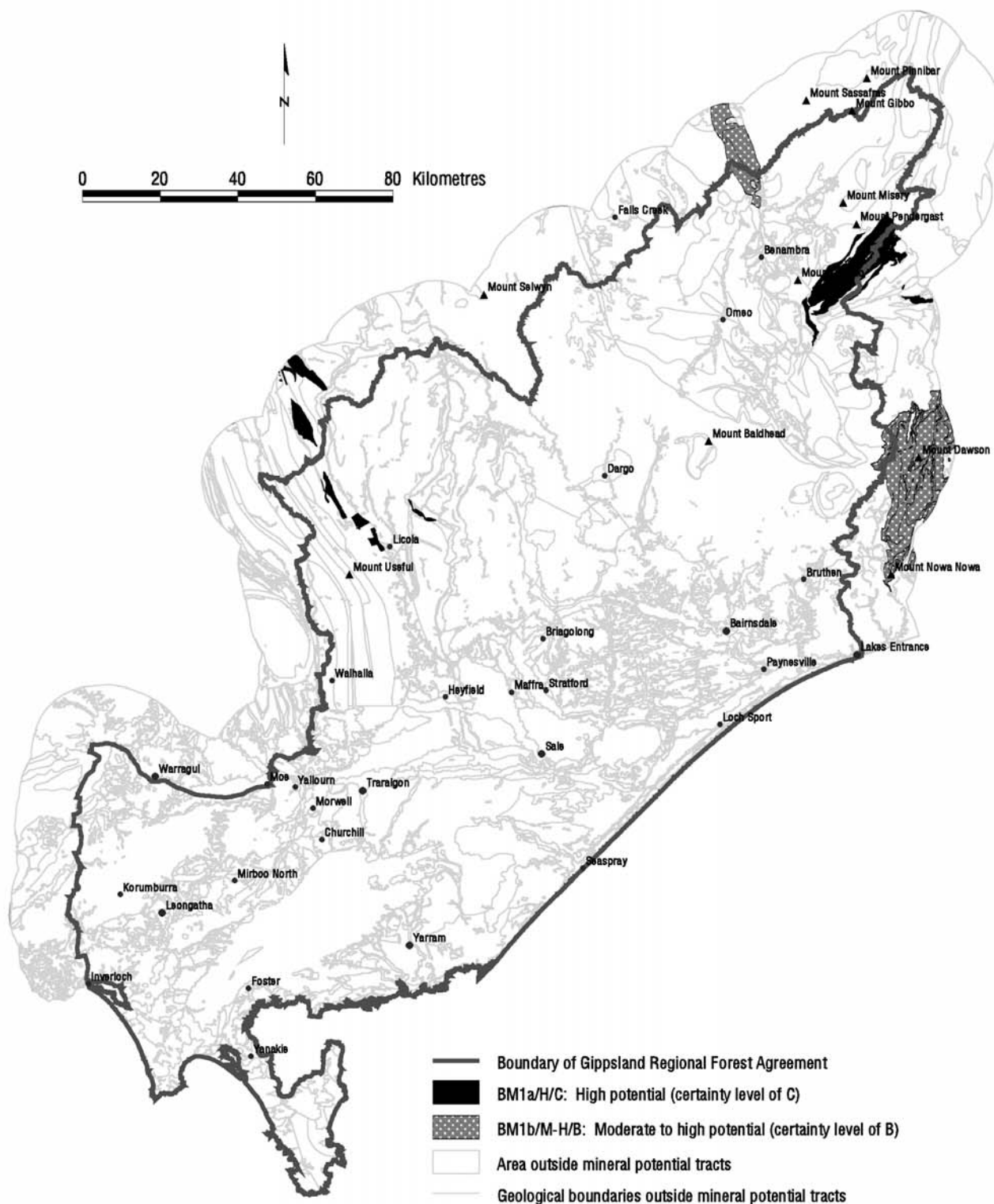


Figure 8 Mineral potential tracts for volcanic associated massive sulphide base metal deposits

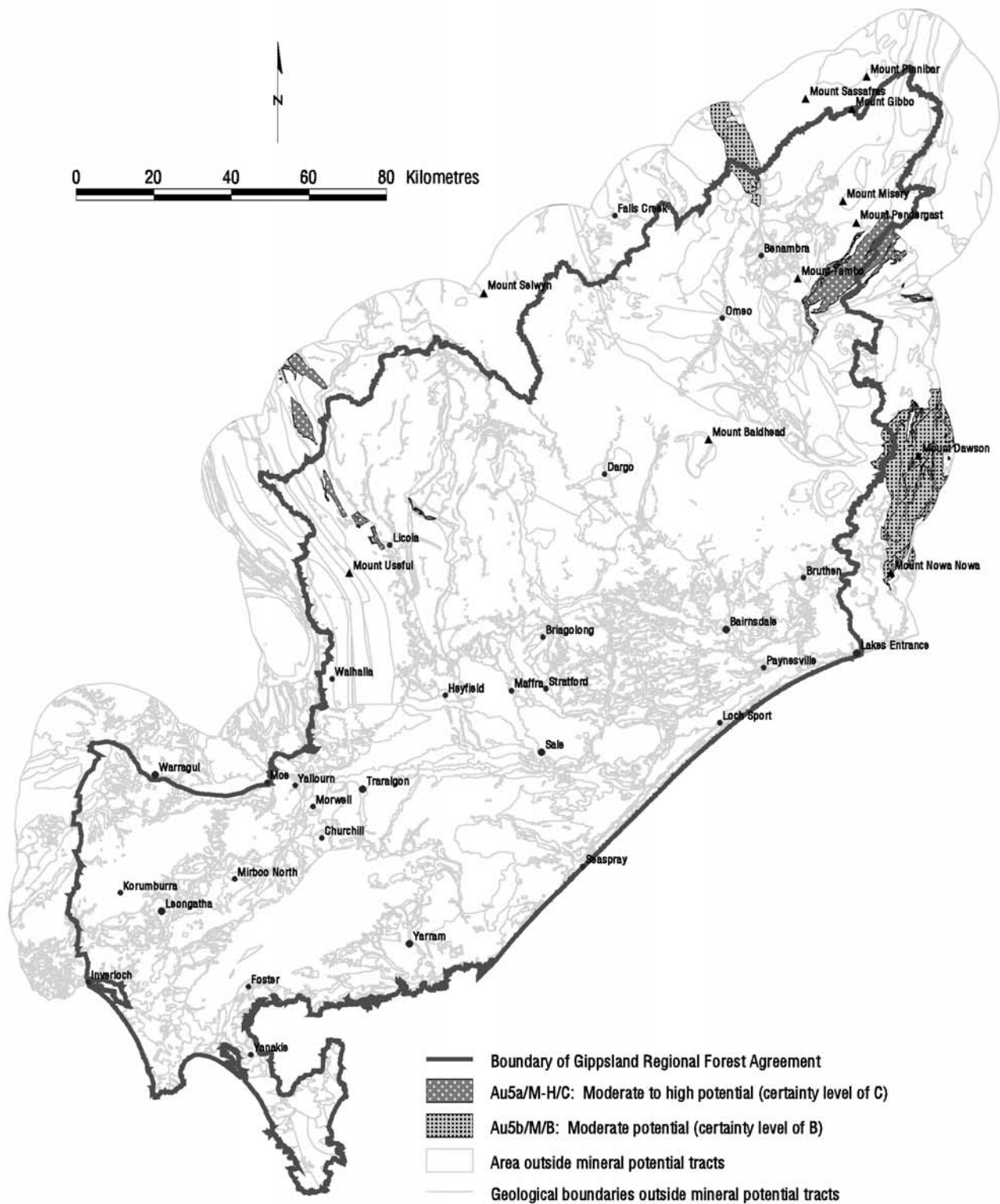


Figure 9

Mineral potential tracts for gold associated with volcanic massive sulphide base metal deposits

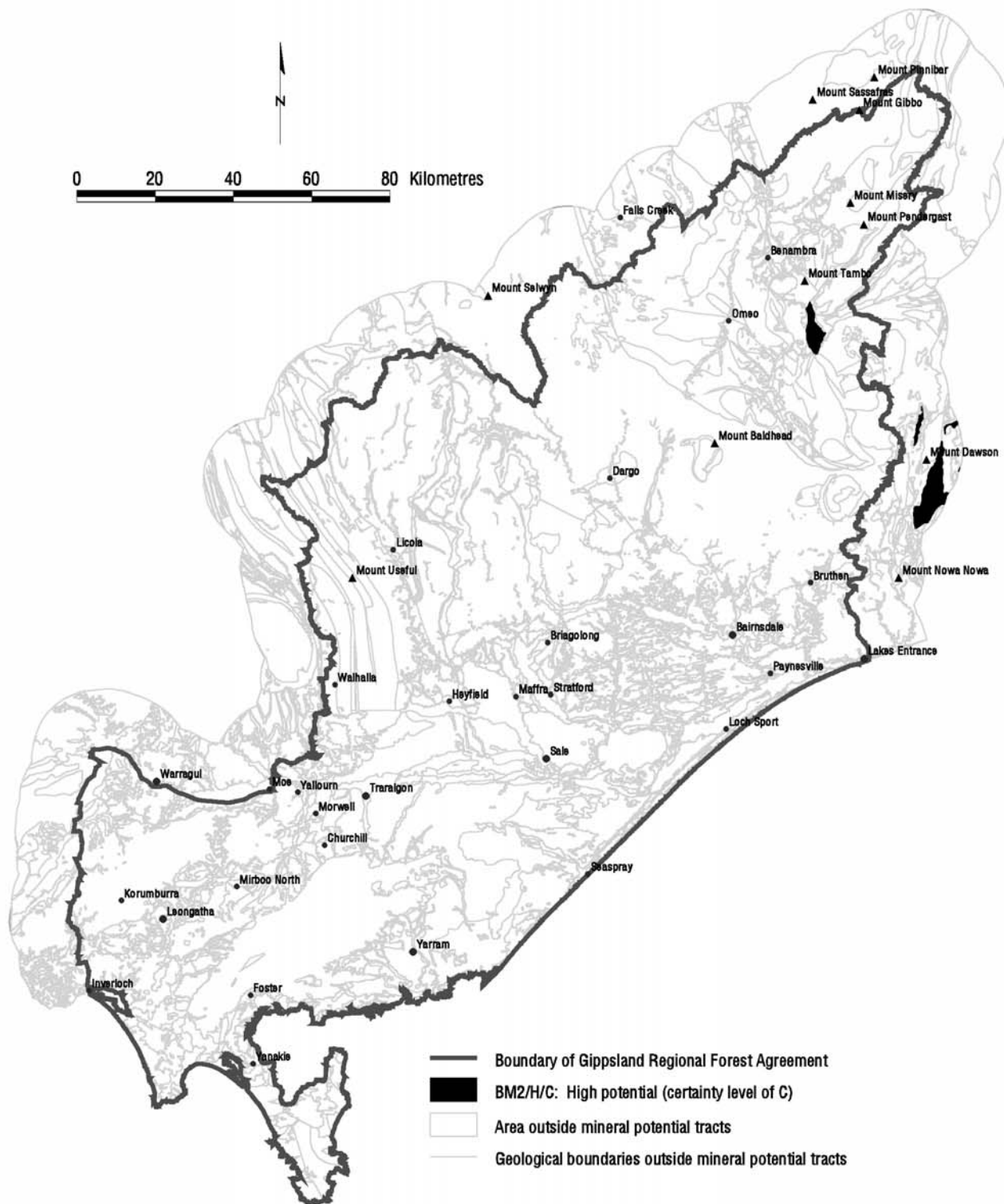


Figure 10 Mineral potential tracts for Irish style base metal deposits

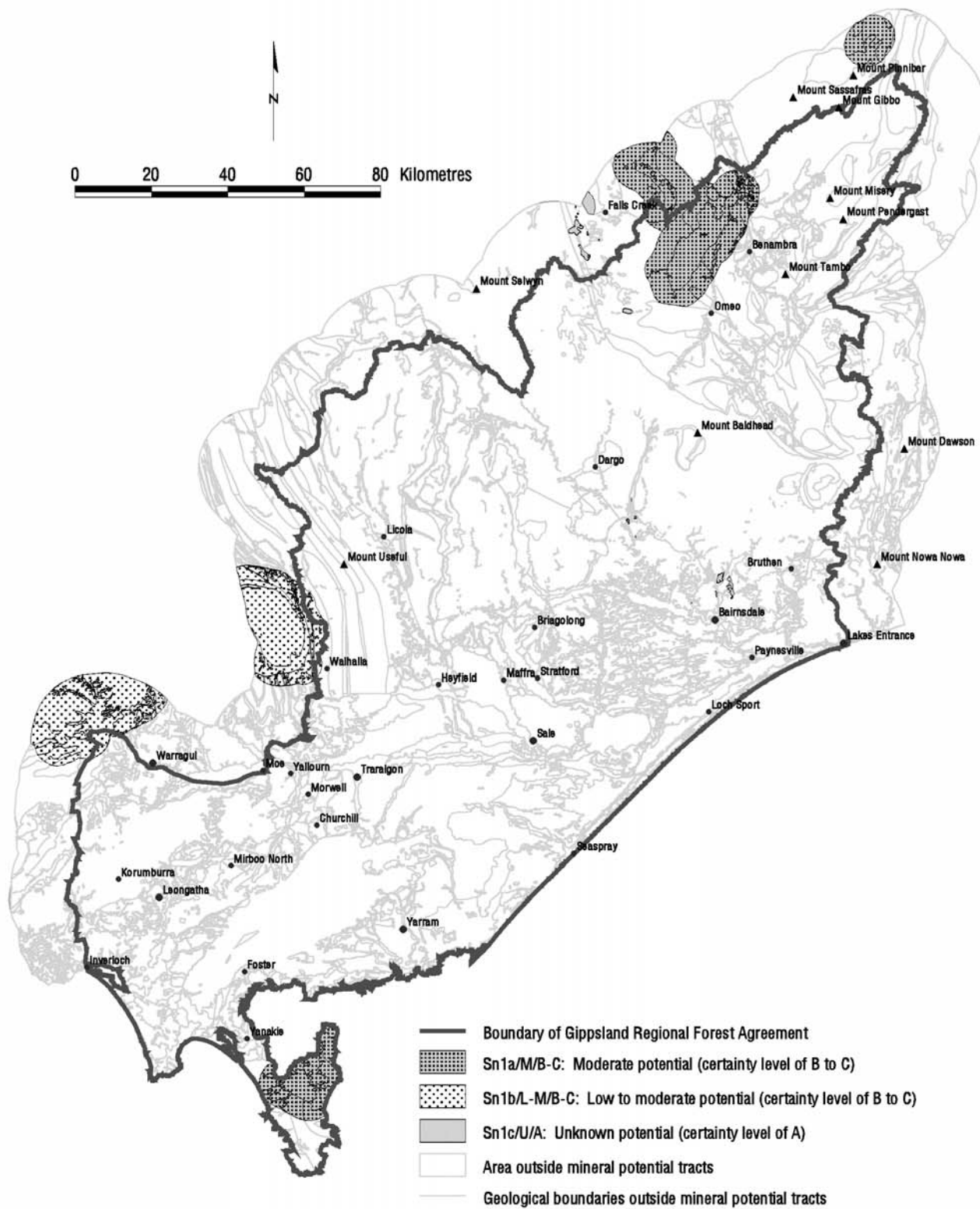


Figure 11 Mineral potential tracts for tin vein deposits

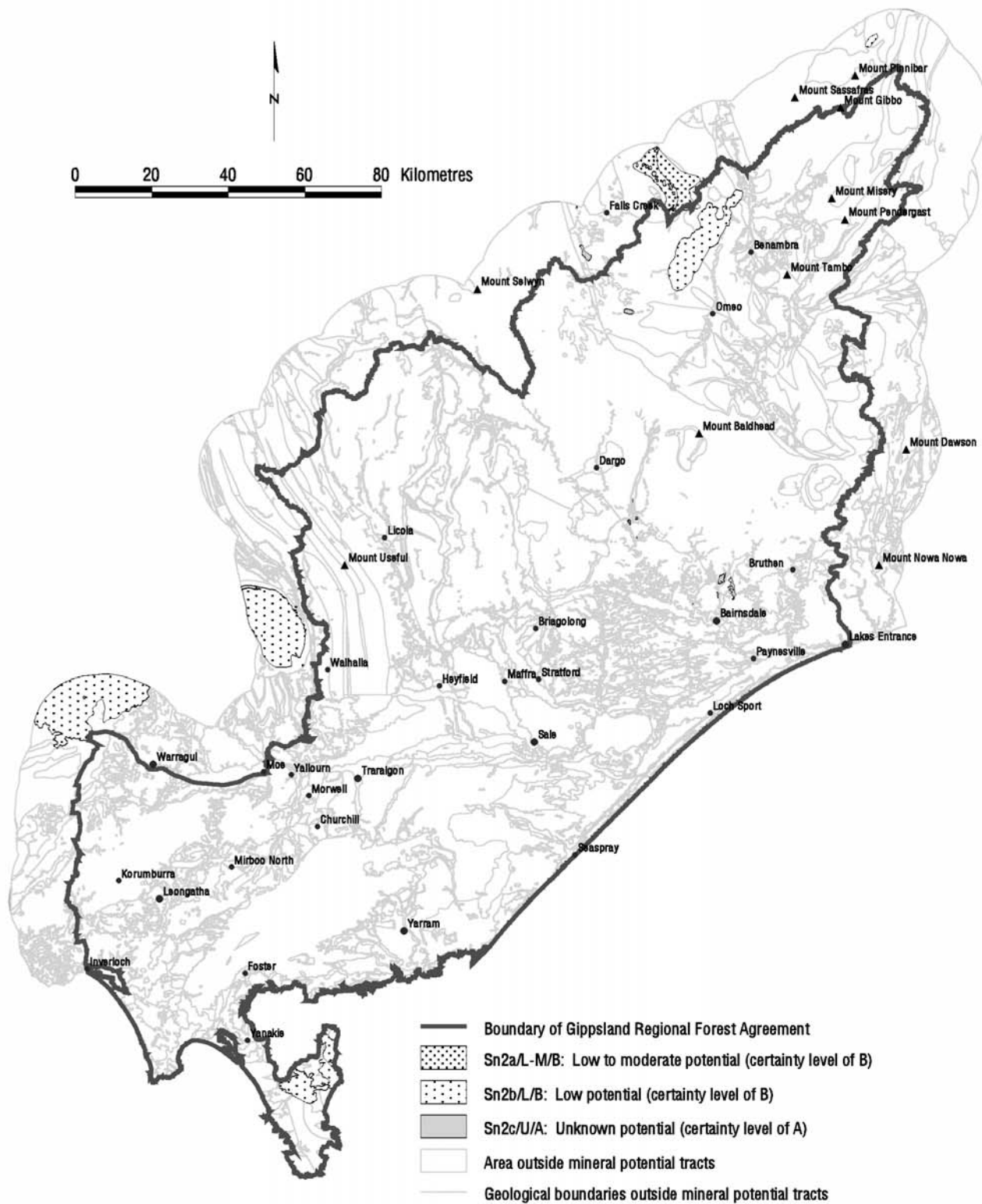


Figure 12 Mineral potential tracts for tin greisen deposits

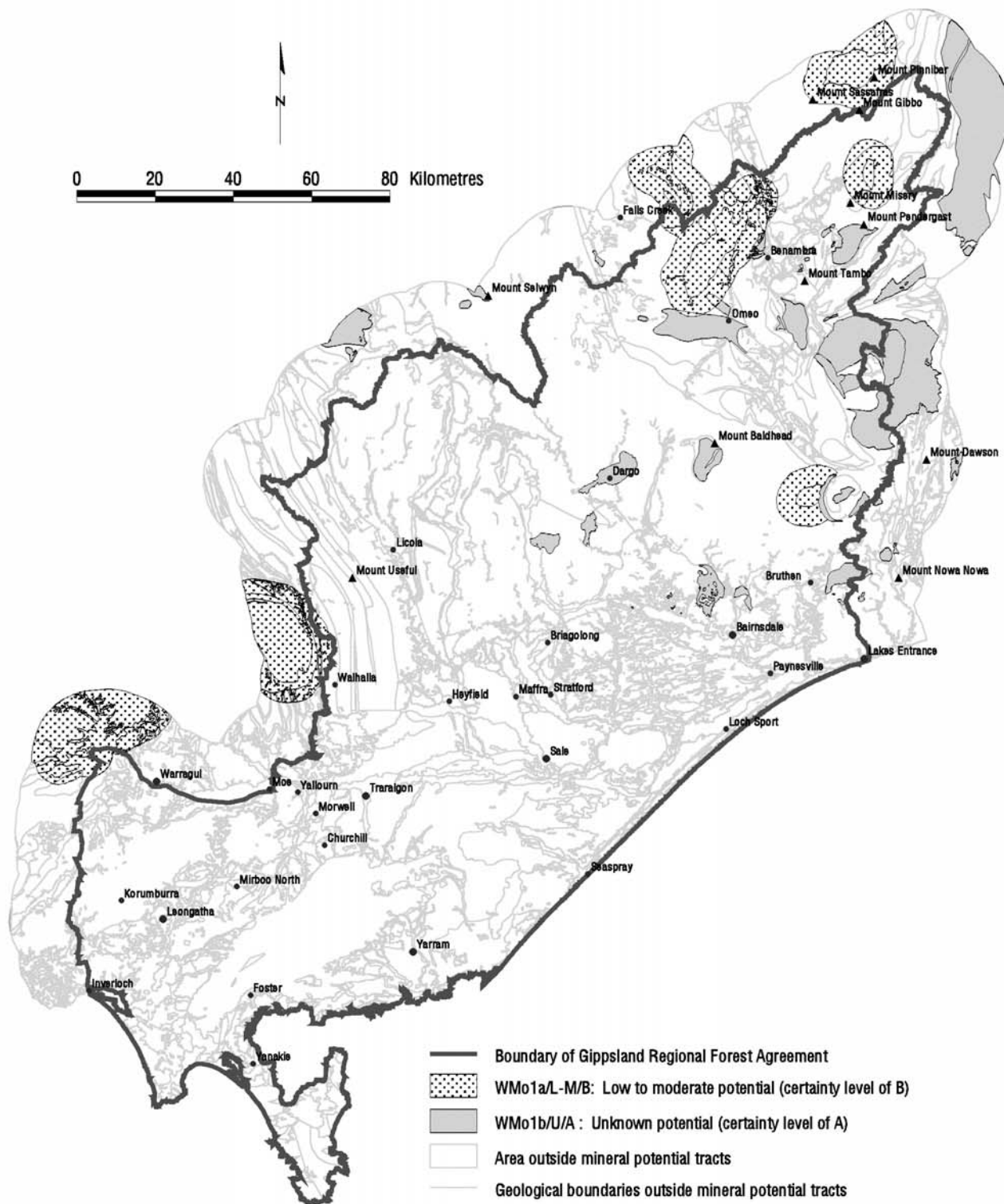


Figure 13 Mineral potential tracts for tungsten-molybdenum deposits

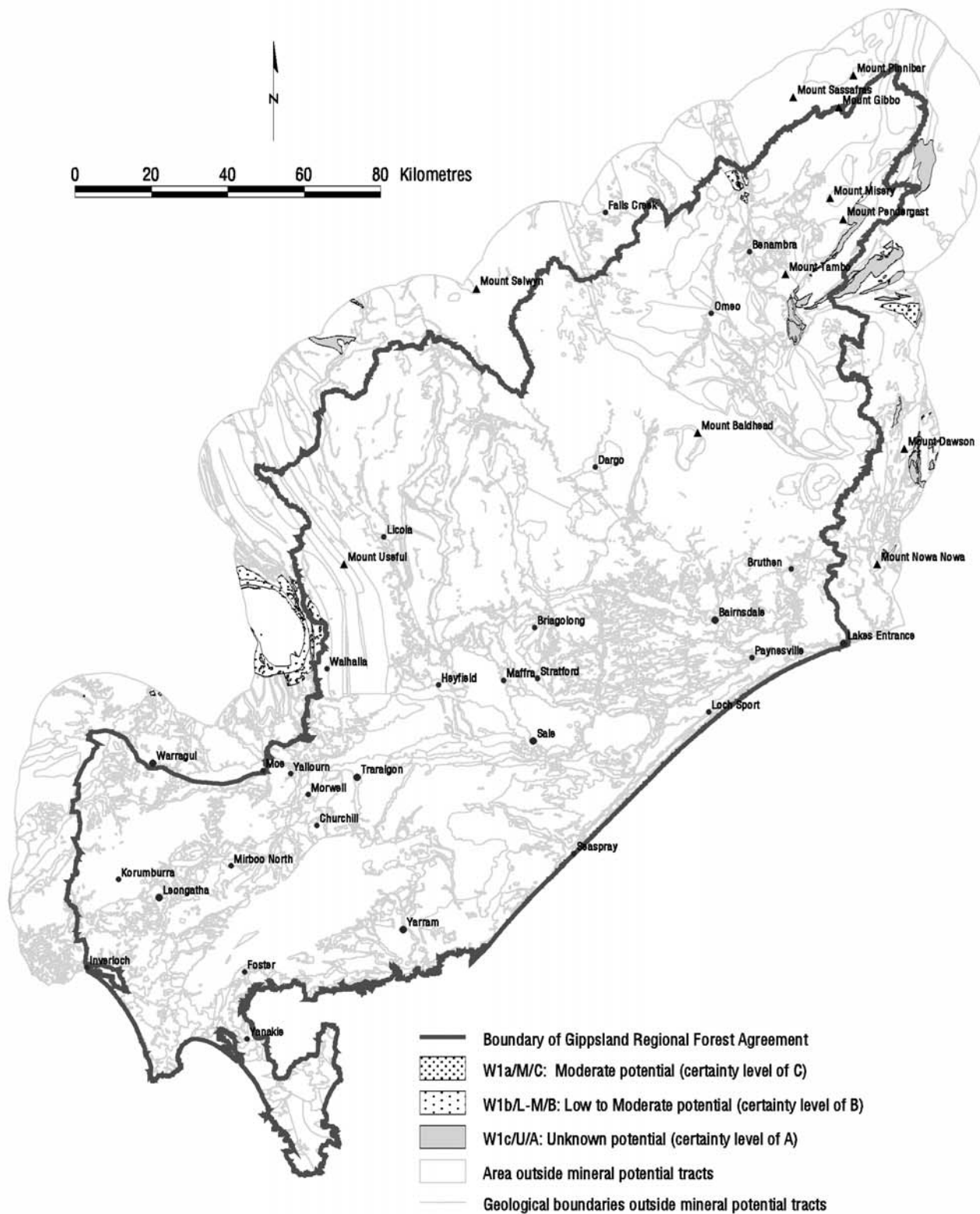


Figure 14 Mineral potential tracts for tungsten skarn deposits

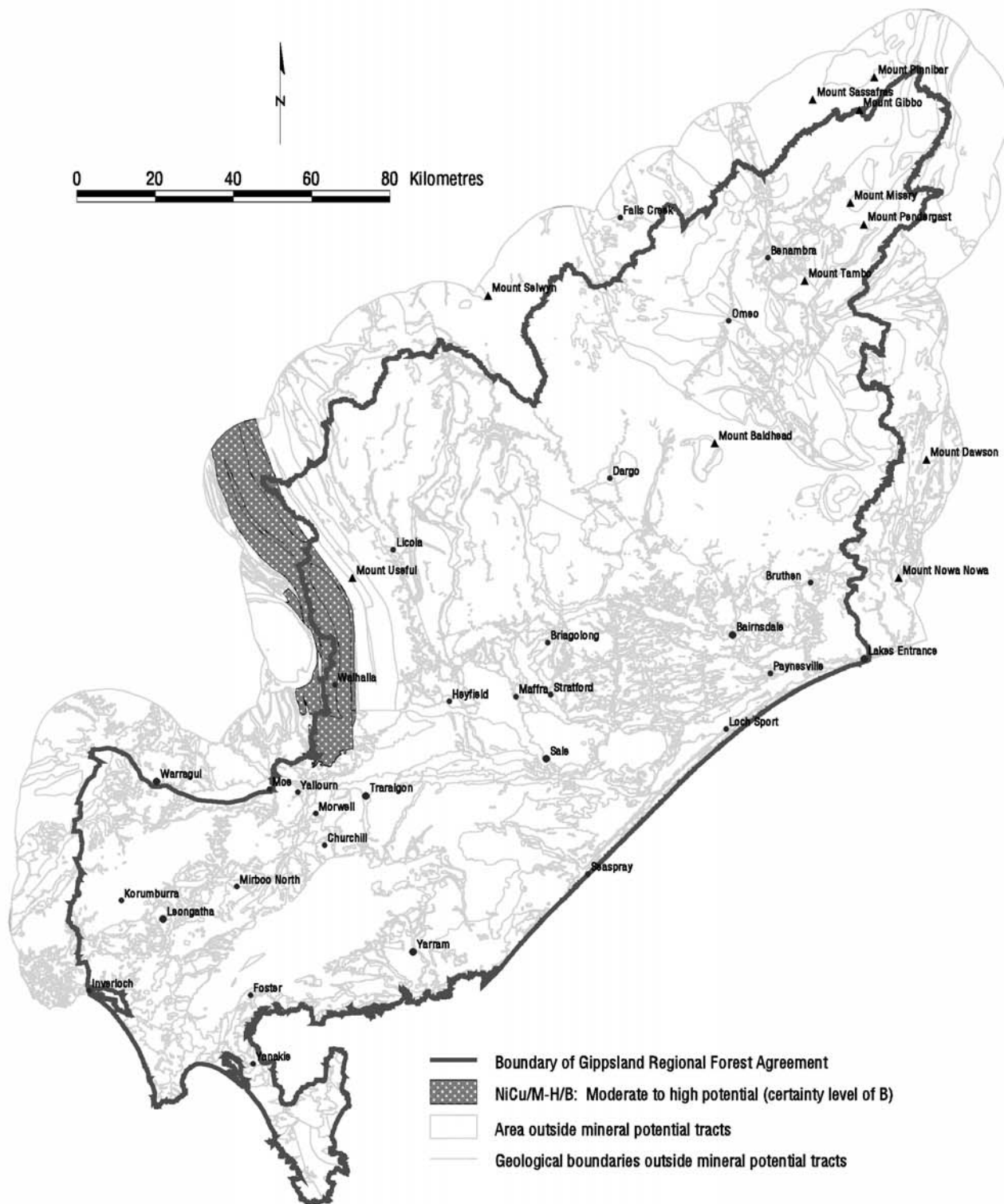


Figure 15 Mineral potential tracts for nickel copper deposits

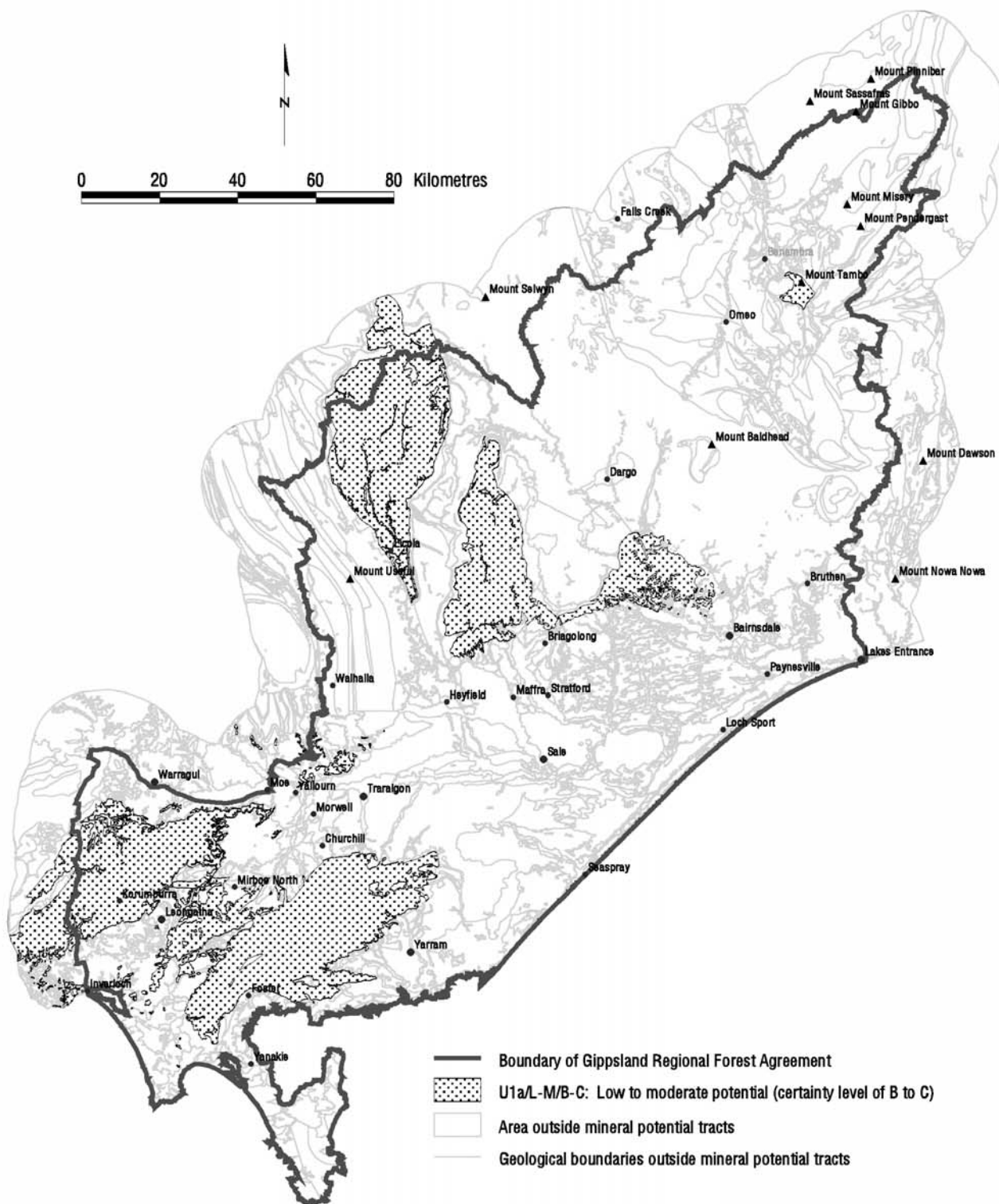


Figure 16 Mineral potential tracts for sandstone type uranium deposits

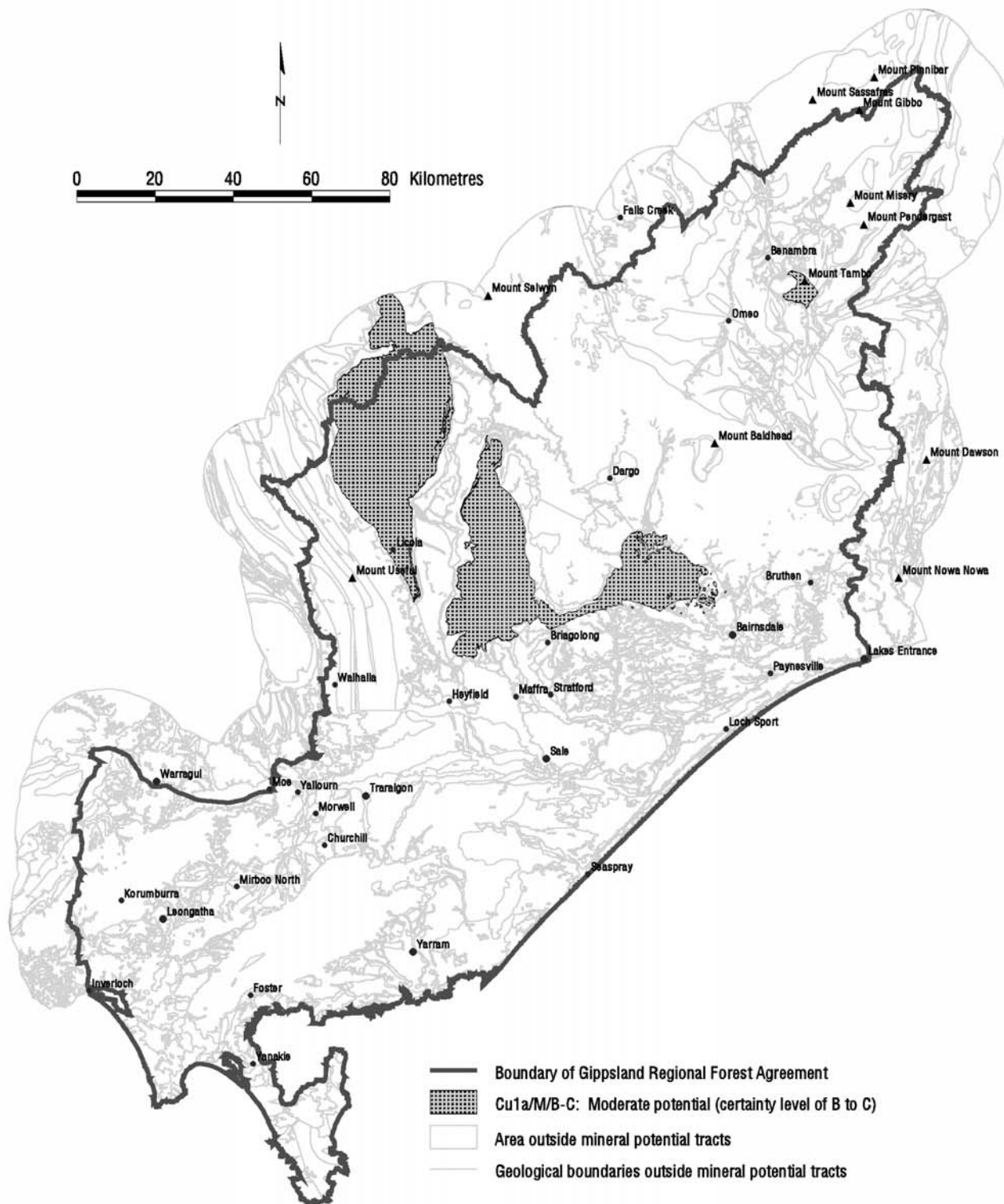


Figure 17

Mineral potential tracts for sediment hosted copper deposits in red bed sediments

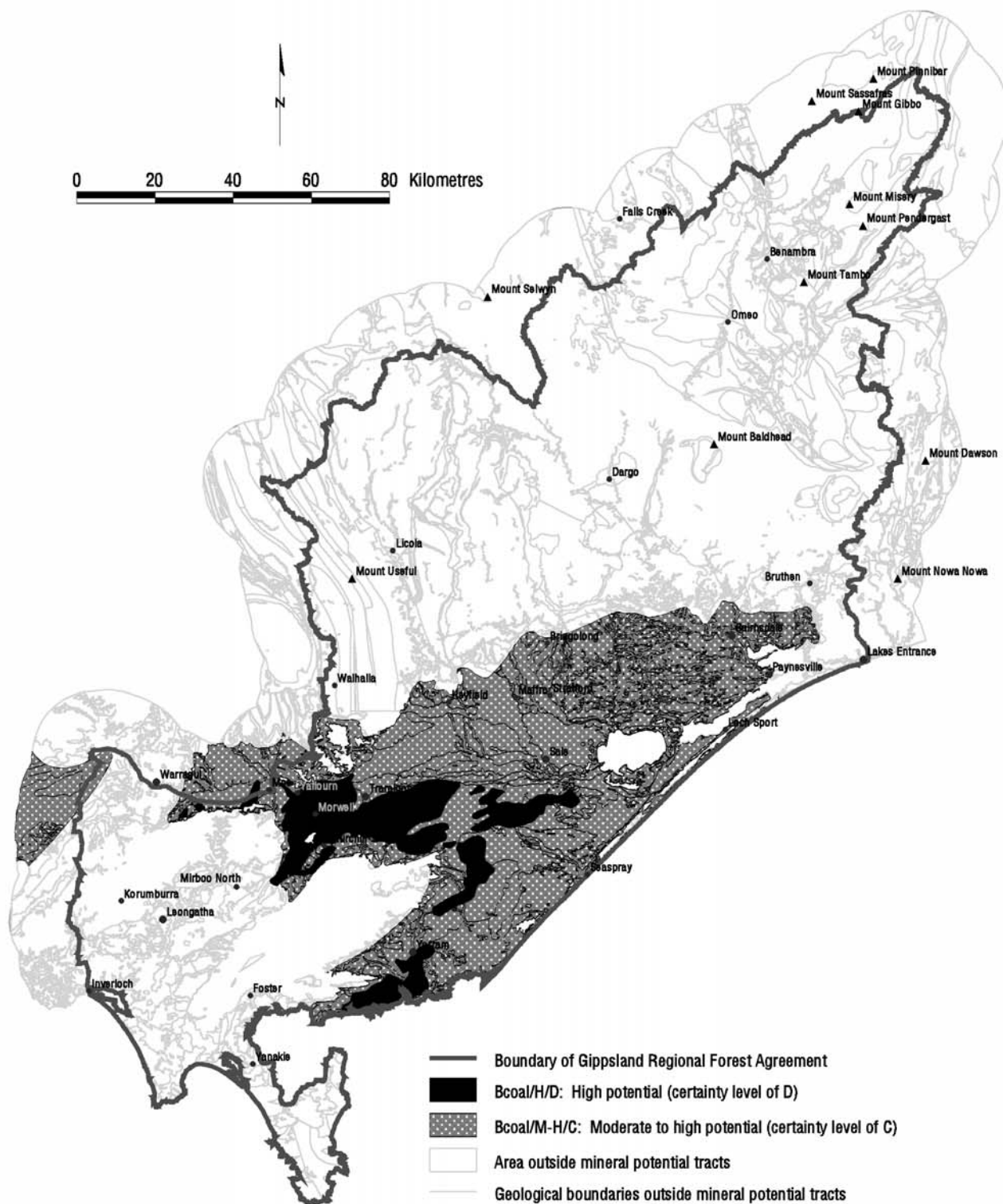


Figure 18 Mineral potential tracts for brown coal

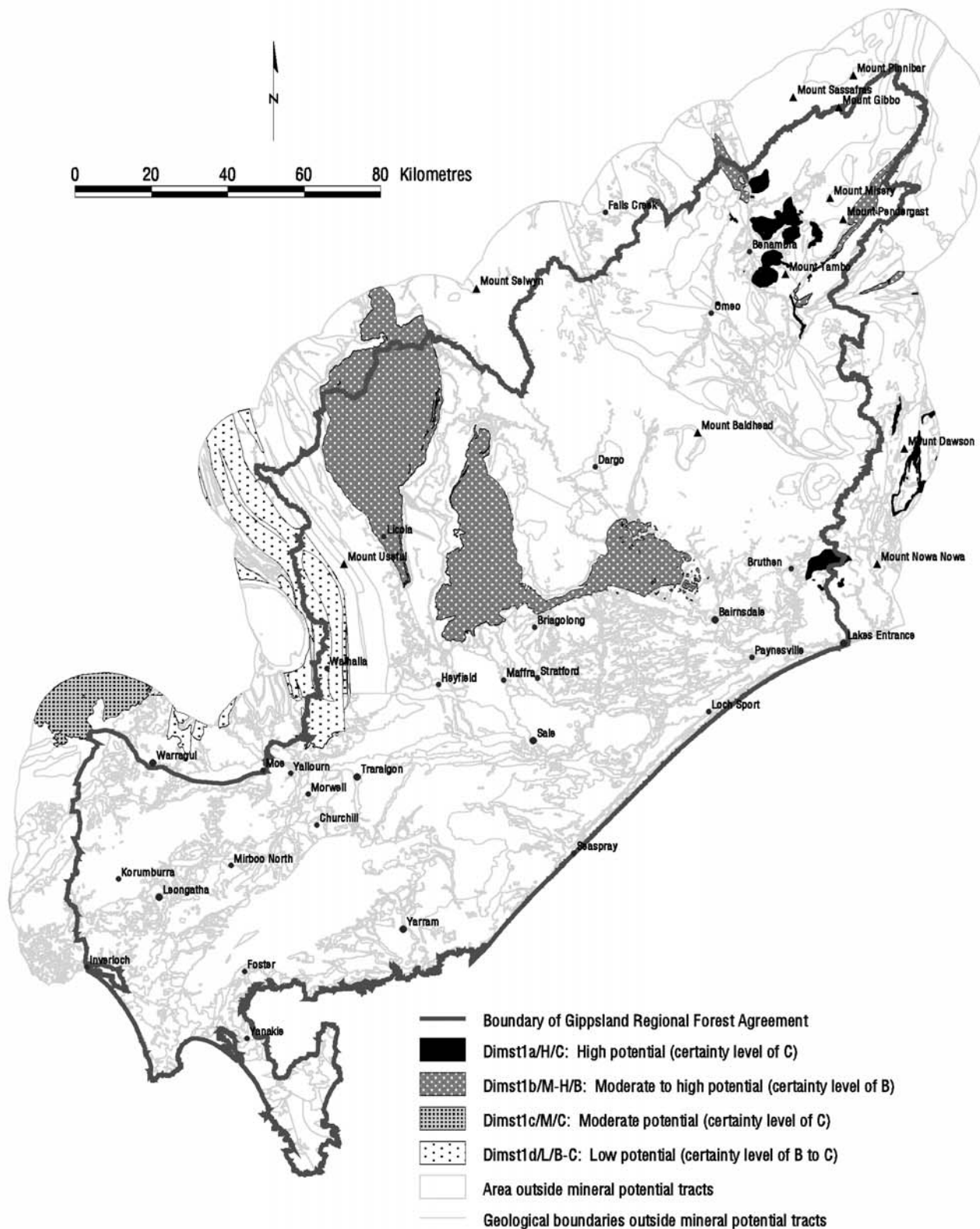


Figure 19 Mineral potential tracts for dimension stone deposits

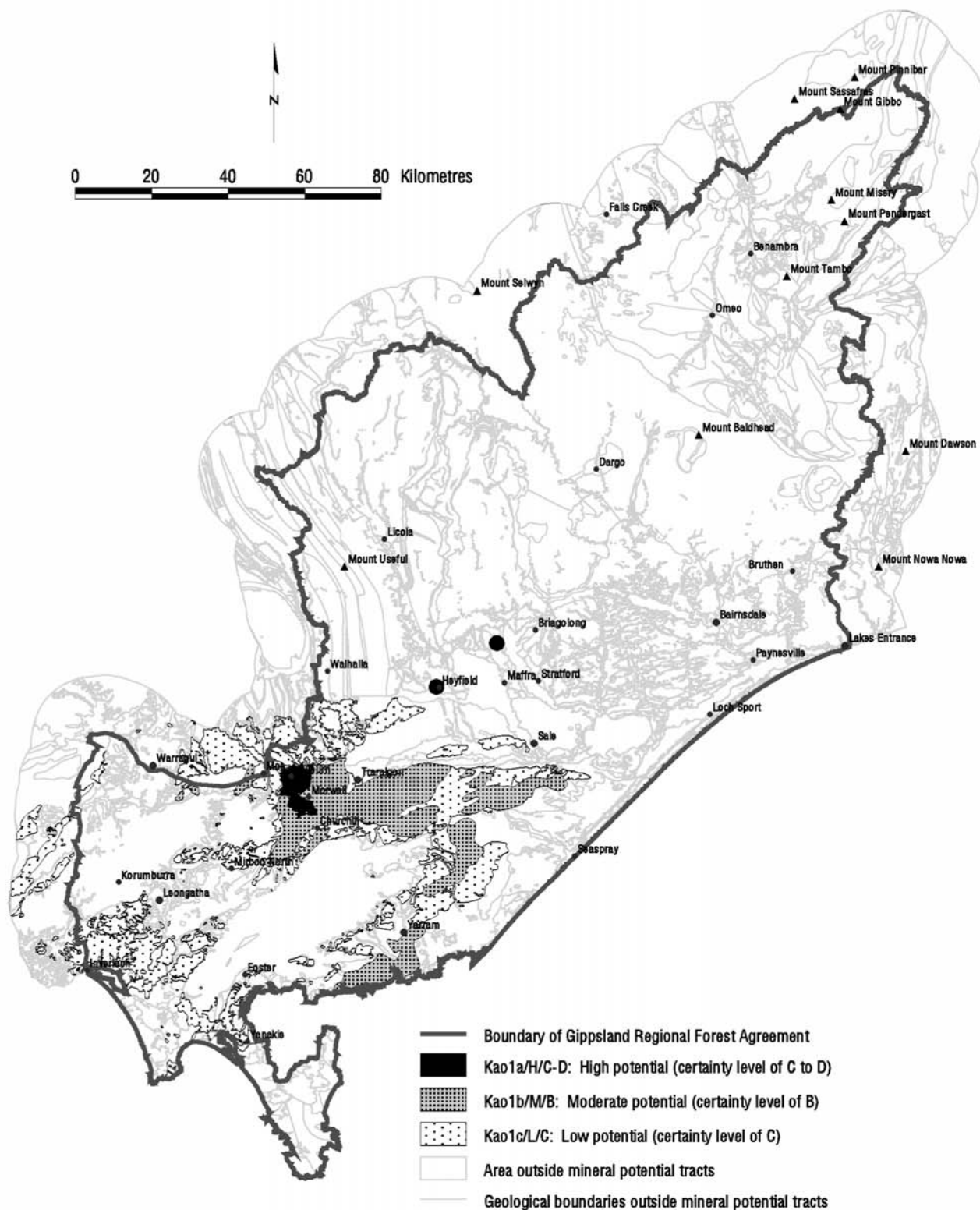


Figure 22 Mineral potential tracts for kaolin deposits

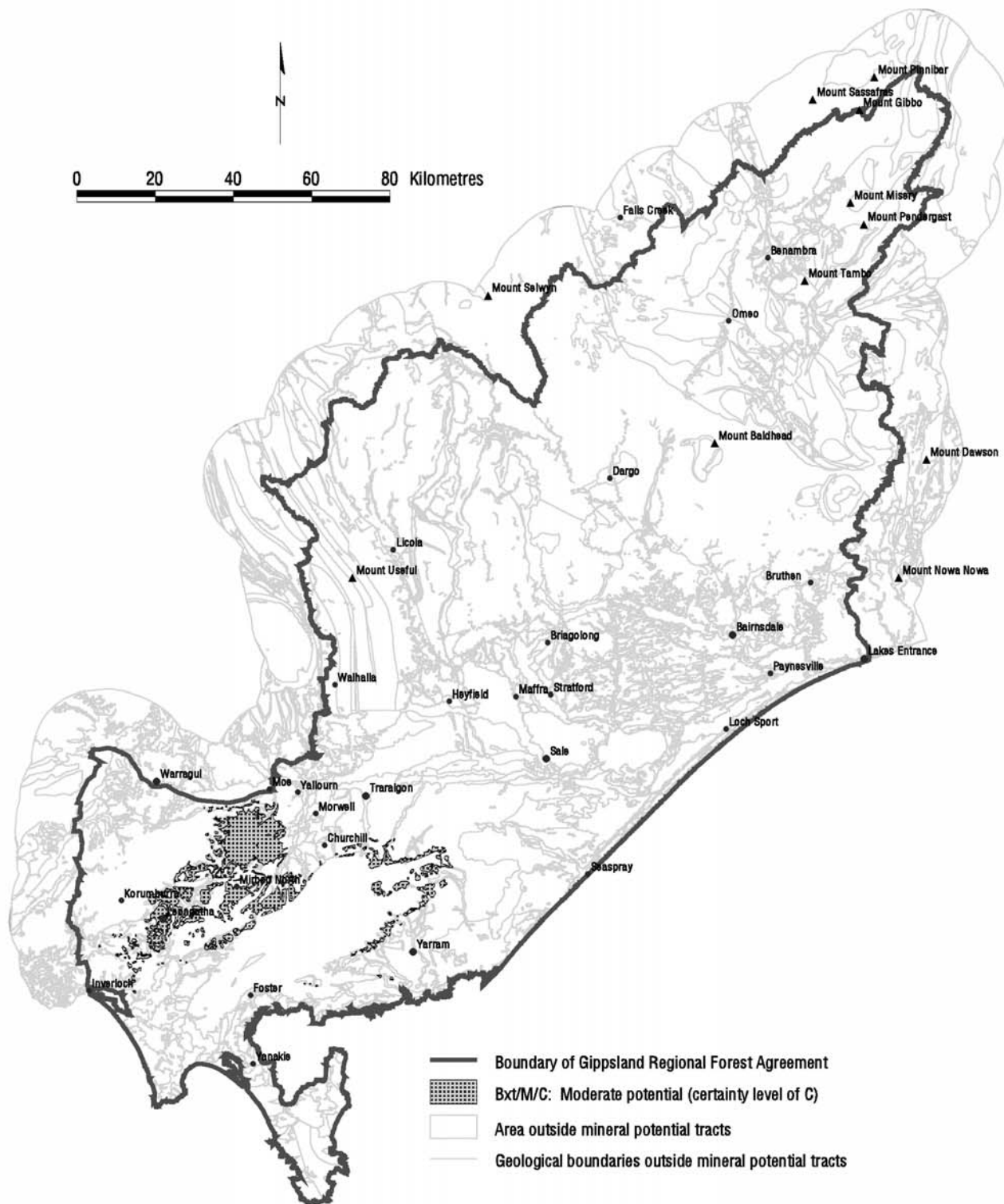


Figure 23 Mineral potential tracts for bauxite deposits

Part 2

**Current exploration, mining and
extraction activities and potential
economic value**

Current exploration, mining and extraction activities and potential economic value

The potential economic value of the region's mineral resources is affected by a number of factors including: mineral prospectivity; geological knowledge base and intensity of data over the region, timing and significance of discoveries; future metal prices and mining costs; and rules and regulations governing exploration and mining.

The mineral potential assessment provides an indication of areas of land which are more likely to be most prospective for particular minerals. However, an assessment of the potential value of mineral resources in these areas is not possible without an estimate of the number and type of deposits likely to occur in a particular region. Therefore, it has not been possible to compare the 'mineral' value of particular areas of land that have been assessed as prospective for minerals with other land (whether prospective or not). These limitations, when combined with the dynamic information-gathering nature of exploration, have significant implications for land access arrangements for exploration and mining in these areas.

Current and historical exploration expenditures provide some indication of the potential value of the undiscovered mineral resources of the Gippsland region. This is because a decision to invest in exploration is based largely on a company's perception of the mineral potential of an area, i.e. exploration expenditure will tend to be higher in areas of higher perceived mineral potential. However, given the uncertainty, different risk attitudes of companies and the difficulty of exploration, expenditures only provide an approximation of true prospectivity. Sometimes deposits are found in previously unprospective areas when new ideas or technology are applied where little previous exploration has occurred.

Exploration

While there are presently no significant operating metallic mineral mines in the Gippsland region, exploration expenditure totalled about \$1.1 million in 1997–98. The major commodity target was gold, with interest also in copper and other minerals.

Exploration prior to 1965

Alluvial gold was discovered at Livingstone Creek, near Omeo, in 1851 and at Cobungra River in the Dargo High Plains goldfield in 1852. Major goldfields established during the early days (from north to south) included Omeo, Dargo High Plains, Dargo, New Rush Creek, Swifts Creek, Grant, Haunted Stream and Shady Creek, Yahoo Creek, Bullumwaal, Debtford, Store Creek, Gladstone Creek, and Limestone Creek in the far northeast and the Woods Point-Walhalla region in the far west of the area. Mining of alluvial gold was extended with the arrival of low-cost alluvial dredges or floating large-scale processing plants on pontoons, which were introduced in the 1890s and early 1900s along Livingstone Creek, and later on Swifts Creek, ending in the early 1920s.

Exploration from 1965 to the present

An Exploration Licence system was introduced by the Department of Mines and Industrial Development in the mid-1960s, which allowed exploration of large areas. This greatly facilitated company-scale exploration for minerals. Since 1965, almost 200 Exploration Licences have been granted over the Gippsland region or its margins (Figure 24).

Exploration in the central-western and north-eastern portions of the region has been hampered by rugged topography, difficult access and at times severe weather. Hence, at least some exploration programs in the region may have been inconclusive and significant mineral deposits may remain undetected and a number of quite prospective areas remain, to a large degree, untested.

The exploration targets sought since 1965 have varied in accordance with relative metal prices, perceived prospectivity, relative recovery costs of metals and new exploration paradigms or mineral deposit models. Until 1967, the gold price was fixed at a relatively low level compared with its post-1980 price, although base metal prices were relatively strong in the 1960s and 1970s. Gold prices did not begin to move rapidly upward until after 1972. Commodities explored for in the region include gold, silver, copper, lead, zinc, platinoids, tin, tungsten, molybdenum, uranium and fluorite.

During the mid to late 1960s reef gold mineralisation was targeted by Planet Mining Co concentrating on old mine workings in the Omeo, and Dargo-Harrietville areas, while Conwest (Australia) prospected for alluvial and lode gold in the Wombat Creek area. In 1966 Australian Geophysical carried out an extensive stream sediment survey in difficult country east of Benambra and extending northeast to Limestone Creek and southeast into the Benambra gold province, uncovering many basemetal anomalies, some of which were followed up by other companies years later.

The mining boom of the late 1960s and the strong upward movement in the gold price during 1972 and 1973 led to a peak of 11 Exploration Licences being granted during 1973. Of these,

four were for alluvial and lode gold in the Dargo-Bullumwaal-Store Creek Goldfields, while basemetals of both volcanogenic massive sulphide (VMS) and Mississippi Valley/Irish Base Metals type in limestone/dolomite were targeted by the remainder.

During the period 1965 to 1973, the area attracted around 44 companies most of whose exploration targets were either base metals, gold or tin/tungsten, although uranium was sought by Conzinc Riotinto of Australia Exploration near Limestone Creek in 1972, and heavy mineral beach sands were targeted in Tertiary sediments of the Gippsland Basin lapping onto basement in the Stratford region by Strahan Sands in 1971. Rio de Janeiro Mines Pty Ltd were the first to explore for carbonate-hosted Mississippi Valley Type (MVT) lead-zinc-silver in the Buchan region in 1966 and that company and Pickands Mather & Co International first explored there during 1967 to 1970 for porphyry copper mineralisation in and around plutons intruding the Devonian Snowy River Volcanics. From 1968 to 1970, both Conzinc Riotinto of Australia and Gippsland Minerals explored unsuccessfully over areas that were later to yield the Wilga-Currawong VMS discoveries east of Benambra. Tin and tungsten were sought in the Glen Wills-Sunnyside and Limestone Creek areas by Gippsland Minerals in 1969–70. In 1972, Endeavor Oil Company NL sought alluvial gold in the Dargo High Plains and Grant Goldfields, and Western Mining Corporation Ltd targeted VMS-style deposits in the area east of Benambra, while Comalco Ltd explored for fluorite in the Devonian limestone around Buchan.

After the lull in exploration activity from 1975 to 1978, during which there was some ongoing interest in MVT and Volcanic Massive Sulphide (VMS) base metal targets in the Buchan and Benambra areas respectively, the period 1979 to 1981 witnessed a growth in exploration activity based on strong interest in base metals and also tin, molybdenum and gold within the region. Exploration for base metals included a strong interest in MVT lead-zinc-silver in the Buchan Limestone by Preussag Australia Pty Ltd while exploration for VMS in volcanics in the region was stimulated by WMC Ltd's 1978 announcement of the discovery of the Wilga copper-lead-zinc-silver-gold deposits in the area east of Benambra. In late 1977, sedimentary uranium and vanadium were targeted in Tertiary sediments of the Gippsland Basin unconformably overlying Palaeozoic basement in the area north of Maffra-Stratford by Northern Mining Corporation NL. The tin boom of 1979–80 resulted in Freeport Australia exploring for vein and porphyry-type tin deposits in and around granitic bodies near Omeo and south-east towards Buchan, while the soaring gold price at that time resulted in accelerated interest in lode and alluvial deposits in the Dargo and Gladstone Creek goldfields as well as in the small Tara goldfield south-east of Buchan.

Exploration activity peaked again in 1981 when 12 Exploration Licences were granted. Apart from exploration for tin, gold and base metals, particularly porphyry copper-gold, there was a burst of interest in brown coal within the Tertiary Gippsland Basin sediments stretching from Orbost westward to Stratford, where seven Exploration Licences were granted, four to BHP, one to BP Mining & Development, and two to Shell Australia.

The period 1982 to 1986 saw a general decline of exploration interest with an average of around five licences per year granted during 1984 to 1986, with the emphasis changing from VMS targets in volcanics to more pure gold-type exploration targets. However, in the period from 1986 to 1989, the number of licences granted increased to peak at 12 in 1989. Apart from minor interest in porphyry molybdenum, platinoids and base metal targets, most exploration was concentrated on porphyry gold-copper, epithermal gold, slate belt gold and lode-type, replacement, and disseminated-type gold targets, as well as alluvial gold.

The pattern of exploration during the 1990s was similar with gold being the principal commodity targeted. Exploration seemed to drop off markedly after 1990 and did not show any improvement until 1996 when 10 licences were granted. In the period 1991 to 1998, the

whole range of gold deposit types was sought within the area and included porphyry gold-copper deposits. There has been intensive interest by BHP in MVT lead-zinc-silver deposits within the limestones and dolomites of the Buchan Basin since 1990. Also there has been continuing interest in VMS-type basemetal deposits by Denehurst Ltd which was granted a licence in 1996.

From the beginning of 1984 to the end of 1998, the major exploration focus in the region has been for gold and about 76 Exploration Licences were granted during this time. The number of Exploration Licences granted annually fluctuated between none in 1991 and 12 in 1989.

About 90 per cent of exploration was directed at gold, while VMS and MVT base metals were targeted (about five per cent) as well as porphyry copper-gold-type deposits (about five per cent).

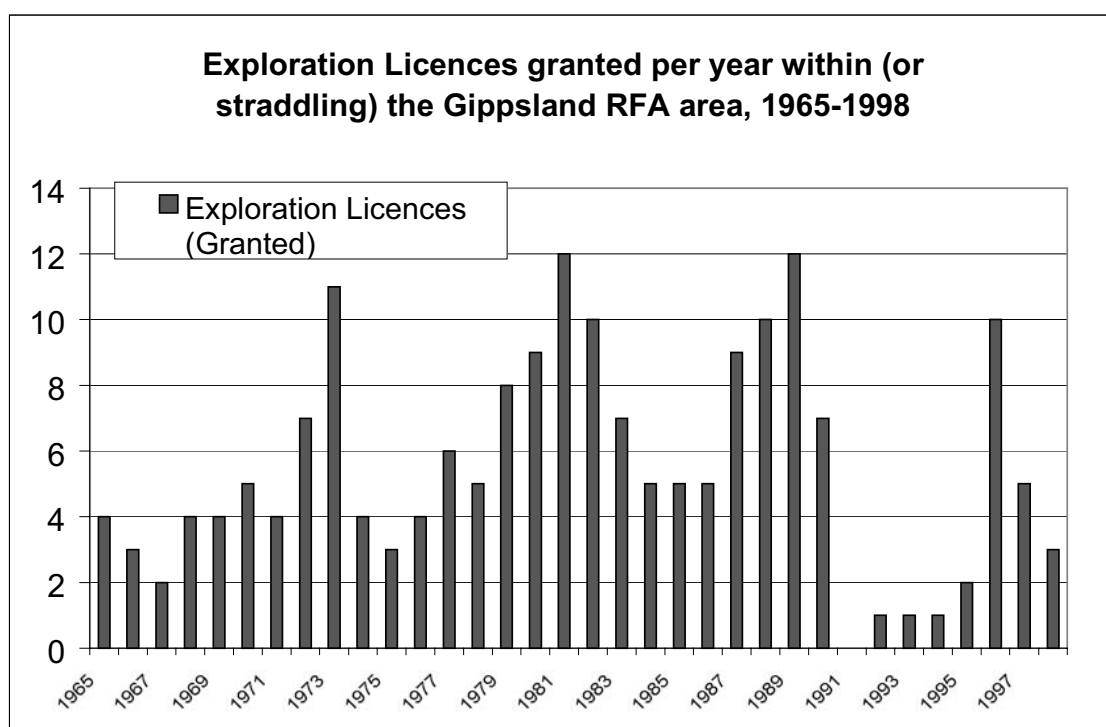


Figure 24 Exploration licences granted for the Gippsland region

In 1997–98, total exploration expenditure in the Gippsland region was about \$1.123 million (Minerals and Petroleum Victoria 1998), being \$1.119 million on Exploration Licences and \$4 200 on exploration under Mining Licences (Tables 13 and 14).

Table 13 Total mineral exploration expenditure, Gippsland region, 1991–92 to 1997–98

(1997–98 dollars)

Year	Exploration expenditure (\$)	Victorian exploration expenditure (\$ million)	Gippsland region expenditure, as a percentage of Victorian expenditure
1991–92	8 192	11.3	0.07
1992–93	80 431	16.4	0.49
1993–94	827 340	20.5	4.03
1994–95	1 580 224	44.3	3.61
1995–96	2 083 090	35.8	5.82
1996–97	1 475 790	37.9	3.90
1997–98	1 123 283	36.6	3.07
Total	7 178 349	202.8	3.59

Note: Figures include mineral exploration expenditure on Exploration and Mining Licences, as derived from Mineral and Petroleum Victoria records. Expenditure expressed in current dollars in each financial year has been converted to constant 1997–98 dollars using changes in the consumer price index.

Table 14 Expenditure on mining licences in the Gippsland region, 1991–92 to 1997–98

(1997–98 dollars)

Year	Mining licences			Number of mining licences
	Exploration expenditure (\$)	Other expenditure* (\$)	Total expenditure (\$)	
1991–92	Nil recorded	Nil recorded	Nil recorded	50
1992–93	30 877	7 956 123	7 987 000	41
1993–94	541 968	9 059 488	9 601 456	33
1994–95	1 045 390	16 492 499	17 537 890	36
1995–96	880 070	12 139 751	13 019 821	31
1996–97	72 610	81 388 006	81 460 616	29
1997–98	4 200	102 852 655	102 856 855	28
Total	2 575 115	229 888 522	232 463 637	

Note: Figures derived from Mineral and Petroleum records. Expenditure expressed in current dollars in each financial year have been converted to constant 1997–98 dollars using changes in the consumer price index. Mining licence exploration expenditure included in Table 13.

*Other expenditure on mining licences includes costs associated with mining and extraction of ore, processing plant, capital costs and rehabilitation.

Mining and quarrying

In addition to expenditure on Exploration licences there has been significant expenditure on Mining Licences in the Gippsland region, which includes expenditure on exploration and development activities (Table 14). Prior to 1996, most of this expenditure was on Mining Licences that overlie historical gold workings as well as the Wilga base metal mine. The significant increase in expenditure after 1996 was due to the inclusion of expenditure on the Latrobe Valley coal mines which were granted a Mining Licence after 1996 as part of the privatisation of the former State Electricity Commission.

As at November 1998, there were 69 current and five applications for construction material Work Authorities in the region. A total of 41 Work Authorities extract sand/gravel, 12 extract basalt and the rest extract limestone, sedimentary rocks, clay/shale and granite. Numerous smaller pits used for minor rural road maintenance are not covered by these Work Authorities. Construction materials worth approximately \$2.2 million were extracted in 1994–95 under the *Extractive Industries Development Act 1995* (NRE records).

A small copper-zinc-silver deposit, the Currawong is about three kilometres north-east of another small base metal deposit, the Wilga deposit that was mined out a few years ago. A case study of this type of deposit was carried out by ABARE for the East Gippsland Comprehensive Regional Assessment (VicRFASC 1996).

Case study—slate belt gold and the Nagambie Mine

While the resource assessment found that the region is prospective for slate belt gold deposits, no assessment was made of the potential number or size of undiscovered slate belt gold deposits that may lie within the Gippsland region. However, the size of identified slate belt gold deposits in Victoria (which contain virtually all the gold mined in Victoria to date) provide an indication of the potential size of undiscovered slate belt gold deposits that may lie within the region.

Of the 163 Victorian slate belt gold deposits surveyed by Bowen (1974), 85 per cent of the deposits had a total production of between 1 000 and 6 228 kilograms (Figure 21). The Nagambie mine which closed after production of 4 185 kilograms (Register of Australian Mining), provides an example of a gold deposit within this range. Moreover, the Nagambie mine occurred close to a small rural town and the history of the Nagambie operation provides a useful insight into the effect that such a mine (if found in the Gippsland region) could have on local towns and regional economies.

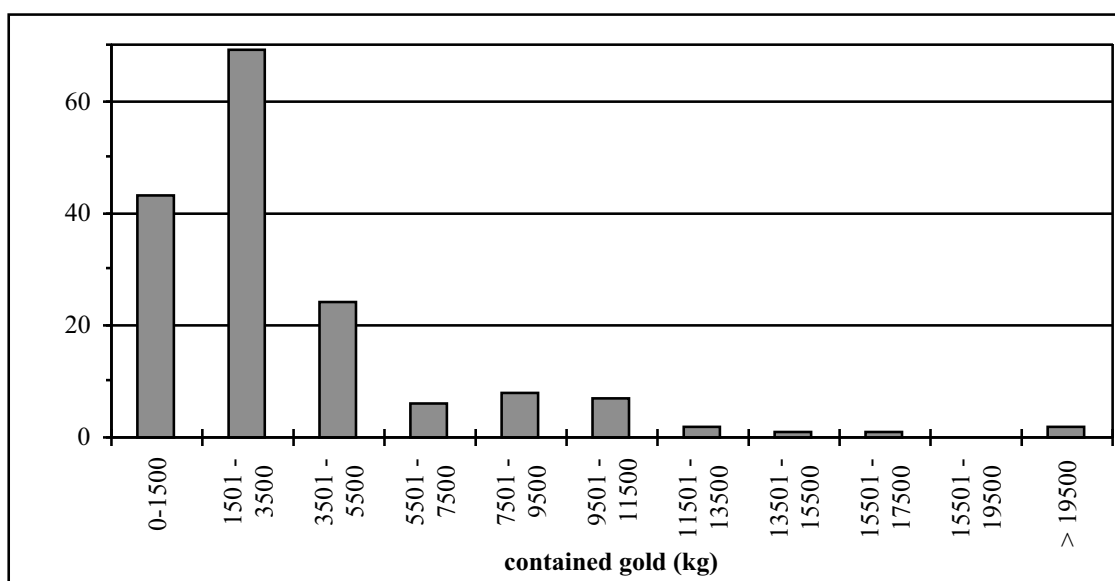


Figure 25 Production from slate belt gold deposits in Victoria, 1857–1974

The Nagambie gold deposit was discovered in 1985 by Frank Green of East Union Prospecting (Hughes 1990). Perseverance Corporation acquired the title over the area in 1987 and began a program of drilling to delineate a resource of 7 million tonnes at a 1.2 grams per tonne gold grade using a 0.4 grams per tonne cut off grade (Hughes 1990). Ore was mined from July 1989 until June 1993, however, spraying of the heap leach to extract minor amounts of gold continued until March 1997. The mine generated gross revenues of around \$74 million over the eight year mine life. Direct employment and gross revenue flows from the mine over its operating life are shown in Table 15.

Table 15 Gross revenue and direct employment, Nagambie Gold Mine

(Real 1995–96 dollars)

Year	Gross revenue (\$)	Direct employment (no.)
1989	2 663 377	90
1990	25 129 676	178
1991	18 095 995	105
1992	12 370 433	125
1993	11 155 253	34
1994	3 387 699	32
1995	1 251 428	21
1996	351 320	14

Source: J. Kelly, Perseverance Corporation Ltd, personal communication, February 1997.

Adding to the net economic benefits associated with the rents from production (not calculated in this report), the Nagambie mine also generated considerable indirect benefits which have been detailed by Sinclair (1991).

- It was estimated that the mine resulted in the stimulation of an additional 73 jobs in Victoria and 7.5 jobs within the Nagambie region through indirect employment multiplier effects.
- Perseverance spent \$465 000 on local infrastructure, which included upgrading the electricity relay station and road improvements. These enabled a \$1.5 million mushroom farming business to establish in the area which created eight new jobs in the region. These benefits are in addition to the multiplier effects described above.

- The mine introduced a variety of workers into the region, increasing the diversity and level of skill in the Nagambie region's occupational structure (31 of the mines' employees were new residents to the area). In addition, the population growth in the region was around 4.5 per cent over the period 1989 to 1991 — reversing the previous trend of population decline in the area.

Mines like Nagambie may be temporary (three to ten years life in many cases) but it is apparent that these projects — in addition to bringing economic benefits to the local and wider economies during their operating life — also provide infrastructure and demographic benefits to smaller communities, which can have lasting effects.

Outlook for mineral production

Developments in world metals markets will influence exploration trends for metalliferous deposits in the Gippsland region. The outlook for the gold and base metal markets is reviewed in this section. Detailed market outlook assessments for the medium term are given in Allen and Evans (1999) and Haine and Berry (1999) for gold and base metals, respectively.

Gold

Historical and projected real gold prices are shown in Figure 26. It can be seen that real gold prices have experienced a clear declining trend since 1980. This trend in price reflected important changes in the structure of the world gold market, which are expected to continue into the coming decade. Over this period annual gold consumption (measured by net additions to stock holdings) declined, while annual non-investment gold consumption (mainly jewellery) increased. The growth in world consumption of non-investment gold has stemmed mainly from changes in a number of developing economies (notably India and China), as incomes in these countries increased. Although non-investment gold consumption has increased faster than world mine production (tending to increase prices), real prices have been prevented from rising by concurrent sales of investment gold bars and coins (by governments and private investors).

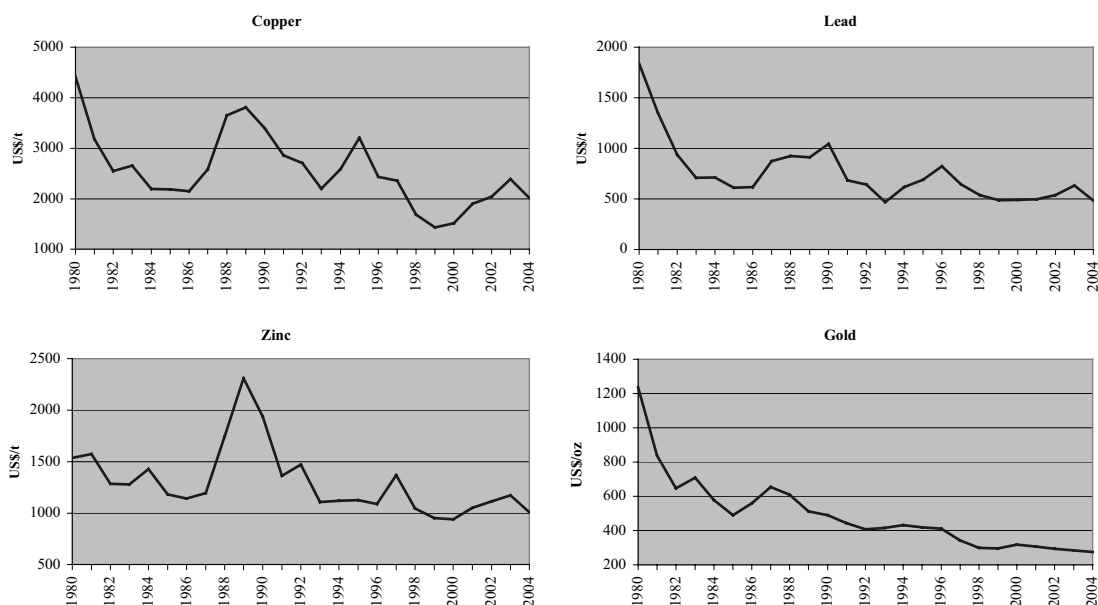


Figure 26 Base metals and gold prices (1999 dollars)

The changing patterns in gold holding and consumption behaviour, which underlie the easing real price, are expected to continue into the medium term. However, it is envisaged that real price falls will be mitigated by three important market influences. First, the official sector faces strong incentives (collectively) to control the rate at which their extensive holdings of monetary gold are sold (and replaced with higher yielding alternative reserve assets). These incentives stem from the requirements of central banks to maintain international financial stability, and the prospect of faster disposal rates rapidly eroding the prices received and

therefore returns from such sales. In addition, recent currency crises may provide encouragement for official purchases in some countries.

Second, demand for non-investment gold use (primarily jewellery) is expected to continue growing strongly, in response to lower gold prices and higher incomes in developing economies which have strong cultural affinities for gold jewellery consumption, notwithstanding shorter term economic disruption in Asia. Third, downward pressures on price will be moderated to the extent that lower prices bring about slower growth of world gold mine output, although it is clear that the gold mining industry is continuing to lower its costs.

Overall, the forecast for strong world demand for gold is expected to be met by expanding mine supply and from official and investment sources. While periodic market imbalances are likely, particularly some shorter term price volatility, the easing trend in real prices seen over the past two decades is expected to be maintained at least over the medium term.

Base metals

Asia (including Japan and China) accounted for 33 per cent of world base metals consumption in 1998, down from 36 per cent in 1997. The fall reflects the current economic downturn in parts of Asia and the share of developing Asian countries is expected to fall slightly in the short term. Over the medium to longer term, Asia's share of world base metals consumption is projected to increase, reflecting a resumption of relatively fast economic growth in these countries.

The developed market economies, which accounted for around 51 per cent of world base metals consumption in 1998, are assumed to continue to expand. Thus, demand for base metals in these countries is expected to continue to grow. Overall, world base metals consumption is projected to increase at around 2.0–2.5 per cent per year over the medium term before easing gradually over the longer term, reflecting expected trends in world economic growth and industrial production.

World mine supply of the three base metals is expected to rise in 1999. World refinery production of the three base metals is expected to keep pace with increases in mine production. A number of large committed and planned development projects are expected to be the major contributors to the projected rise in base metals supply over the next few years. Substantial increases are projected up to the end of 2000 as low cost mines, primarily copper mines in Chile and zinc and lead mines in Australia, commence production. However, these rises are expected to be partially offset by the closure of some older, high-cost producers which are likely to become uneconomic with projected lower prices, particularly for copper.

Over the longer term, continuing technological developments can be expected to place downward pressure on costs. Thus, together with projected demand growth, the long-term downward trend in real prices experienced for each of the base metals is expected to continue. Price projections to 2003 are shown in Figure 26.

Brown coal

Brown coal from the Latrobe Valley Depression in the Gippsland region is the fuel source for just under 80 per cent of Victoria's electricity generation capacity. In 1996–97 the Yallourn Energy, Loy Yang Power and Hazelwood Power companies mined 27.8, 17.1 and

14.9 million tonnes of coal respectively. Production from each mine is predominantly integrated with major power stations of the same name. Known resources at the mines are extensive, with a minimum of 40 years production possible at current levels of production.

Outlook for brown coal

Brown coal is used almost exclusively for electricity generation by power generators in Victoria. The growth in energy consumption in the Victorian electricity generation sector over the past three or four years, apparent in Figure 27, is linked to the effects of recent microeconomic reforms, including the construction of a national electricity market (Bush *et al.* 1999).

Brown coal has benefited significantly from the reforms and in the five years to 1997–98 the share of brown coal as an energy source (excluding hydroelectricity) increased from 42.3 per cent to 47.9 per cent within the interconnected electricity market of New South Wales, Victoria and South Australia. Aside from an underlying increase in electricity demand, a number of reasons explain the comparatively greater increase in demand for brown coal. Primarily, brown coal generators are very low cost producers of electricity. As a result of brown coal's cost advantage, expected low electricity prices in the national electricity market are expected to support the recent high levels of Victorian brown coal production.

Over the longer term, brown coal production and consumption may ease for two broad reasons. First, improvements in thermal efficiency through other generation technologies, against a background of evolving policies on greenhouse gas emissions, are expected to increase the use of other fuels. Second, power generation from brown coal will become more efficient in itself (and require less coal per unit of power output) as old plant is gradually replaced over time.

Information on the expected production and consumption of brown coal in the context of Australia's longer term energy outlook is available in *Australian Energy: market developments and projections to 2014–15* (Bush *et al.* 1999).

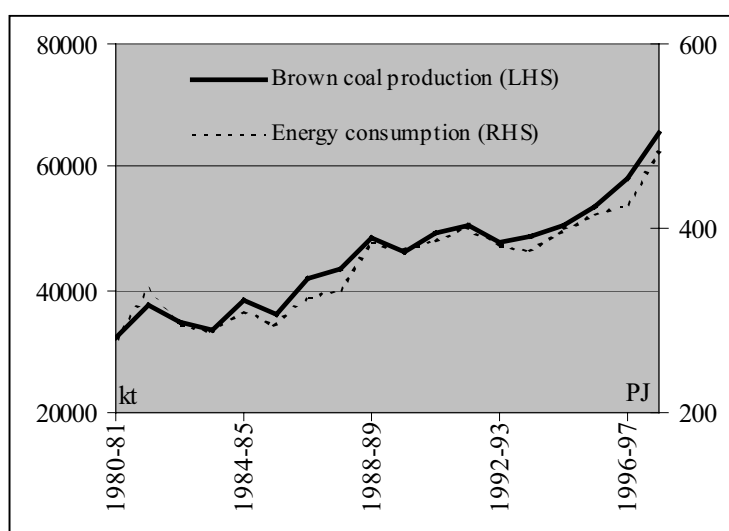


Figure 27 Energy consumption for electricity generation and production of brown coal in Victoria, 1980–81 to 1997–98

Legislation and land access

Access to land is an important issue for exploration and mining. At this stage, the implications of the RFA for exploration and mining in the Gippsland region are not yet known.

It is important to note that no area can ever be classified as unproductive and no assessment of potential mineral resources can ever be considered ‘final’. New information, new concepts and better understanding of geological processes continually change the perceived prospectivity of a region and the availability, usefulness and implication of these can change over time. There are also dynamic aspects to market information that will affect perceptions of a region’s prospectivity, for example mineral prices and extraction costs may change substantially over time.

The nature of access for mineral exploration and mining has a large bearing on the level and type of exploration and mining that occurs in a region. Transparent and well-defined access arrangements reduce uncertainty and facilitate exploration and mining activities. Access provisions of relevant legislation are outlined below.

More detailed discussion of resource access issues relating to exploration, mining and environment can be found in Industry Commission (1991), Cox *et al.* (1994) and Murray *et al.* (1995).

Legislation and regulation relevant to exploration, mining and extractives

In Australia ownership of mineral resources and control of mineral exploration and development largely lies in the hands of the State and Territory governments. The Commonwealth Government has control over mining and exploration activities outside three nautical miles offshore and over radioactive substances in the Northern Territory. Broad Commonwealth responsibilities in such areas as economic policy, taxation, Aboriginal affairs, foreign investment, industrial relations and some environment and heritage issues influence the climate for the resource industry in all states and territories.

The principal legislation covering mining and exploration licences in Victoria is the *Mineral Resources Development Act 1990* (MRDA). This Act is the responsibility of the Minister for Energy and Resources and is administered by the Victorian Department of Natural Resources and Environment. It sets out the rules for granting licences and attaining approval to start operations.

All exploration and mining activities are subject to a range of environmental requirements before, during and after the life of the project, including:

- lodging a rehabilitation bond, before starting an exploration or mining program, to serve as a security should the company be unable to satisfy its rehabilitation liability;
- exploration and mining is subject to standard conditions, and where appropriate supplementary site-specific conditions;
- regular reporting of exploration activities;

- mining and exploration starting only after a work plan has been approved and other approvals obtained; and
- monitoring of environmental management activities by government officers.

Under the MRDA there are four main land types:

- private land;
- exempt Crown land (e.g. National Parks, State Parks and Wilderness Areas);
- restricted Crown land (e.g. flora and fauna reserves and historic reserves); and
- unrestricted Crown land (e.g. State forests).

No exploration or mining activities can be carried out on exempt Crown land, unless the licence was in place before the land became exempt. The approval of the Minister for Environment and Conservation is required before exploration or mining can be carried out on restricted Crown land. On unrestricted Crown land the Minister for Environment and Conservation's consent is not required, however, the Minister must be consulted. Work can start on private land once the consent of the owner and occupier is obtained or compensation arrangements are made.

The principal legislation covering extractive industries in Victoria is the *Extractive Industries Development Act 1995* (EIDA), which provides for granting work authorities for extractive operations. The four main land types under the EIDA are the same as those in the MRDA. Land owner consent is required before extractive activities can be undertaken on freehold land and land manager consent for operations on Crown land.

Mining and exploration is currently excluded from 16 per cent of the land (i.e. Exempt Crown land) in the Gippsland region (Table 16). The consent of the Minister is required for exploration and mining to be carried out within a further 6 per cent of the region (i.e. Restricted Crown land).

Most of the land in the region currently designated as exempt Crown land, the most restrictive category in terms of mining and exploration, occurs within the northern half of the region and does not generally coincide with areas of high mineral potential (Table 12). There is limited overlap between exempt Crown land and listed goldfields. However, significant parts of moderate to high and high potential gold tracts coincide with exempt Crown land. Most of the high potential for gold and porphyry copper in the northern half of the region coincides with unrestricted Crown land or freehold land.

The vast majority of land in the southern half of the region is freehold. There is high potential for brown coal with a high level of certainty on exempt Crown land in the western end of the Latrobe Valley. However, this represents a small proportion of potential brown coal resource in the region (Table 12).

Table 16 Land use categories as a proportion of total land area, Gippsland

Land use category	Area (ha)	Proportion of Gippsland (%)
Exempt Crown land	426 000	16
Restricted Crown land	154 000	6
Unrestricted Crown land	865 500	32
Freehold land	1 231 000	46
Total	2 676 500	100

Source: NRE, March 1999 Victoria

Nature of exploration and mining

Mineral exploration is the assessment of the earth's crust to determine if mineral deposits which can be commercially mined are present. Mining is the commercial extraction of mineral deposits from the earth's crust. While there is often a close relationship between exploration and mining, they are effectively two quite separate activities.

In order to examine the implications of alternative land access arrangements for exploration and mining it is important to understand both the nature of exploration and its likely costs and benefits.

The potential benefits for a private firm from an exploration program derive from the economic returns that will accrue from the discovery of an economic deposit. Given that exploration is a high-risk activity (i.e. there is a small probability of any one venture being successful), companies will approach exploration in a sequential and systematic fashion. This enables the decision to abandon or keep exploring in the area to be made in an efficient manner.

The cost and duration of exploration programs vary from company to company and across commodities. Clark (1996) suggested that the development of a typical major deposit (worldwide) involves a five to twenty year lead time. This estimate results from a typical three to ten years exploration program before the mine development phase.

Exploration is primarily an information-gathering process so it is necessarily dynamic, and most regions can never be regarded as 'completely explored'. Many recent Australian discoveries have occurred in known mineral provinces that have been the subject of exploration efforts for over 100 years. There are a number of reasons for continuing exploration in such areas. Technology and scientific understanding of geological processes continue to develop with time. These advances not only encourage exploration in areas where prospectivity was previously considered low, but also lower the costs and increase the efficiency of exploration (e.g. in highly prospective areas such as Kanowna Belle in Yilgarn, WA and Century in the Mount Isa Inlier, Qld or in areas not previously known to be of very high potential, e.g. Olympic Dam on Stuart Shelf, SA). Further, changing economic conditions (e.g. changes in metal prices or the costs of extraction) affect the expected returns from exploration and can significantly affect the level and type of exploration.

The exploration process starts with assessments of very large regions and is then systematically narrowed down as the exploration target becomes better defined. The direct costs facing explorers increase as the target area becomes smaller and exploration methods become more intense. The environmental impact associated with exploration also increases as the area being explored becomes smaller and the exploration methods used become more invasive (e.g. drilling), unless special steps are taken to reduce such impacts.

Exploration methods used in the Gippsland region include:

- **regional reconnaissance** using remote sensing techniques such as satellite imagery, aerial photography and regional mapping. This exploration phase has little, if any, impact on the land. Activities may cover hundreds of square kilometres in order to identify areas of exploration interest. Geological mapping involves the search for and examination of rock outcrops and exposures in a licence area;

- **sampling** in the field which usually involves taking small rock chip, soil or stream sediment samples. Samples are typically obtained by shovel, hand auger or hammer. More intensive sampling and localised mapping may also be carried out using trenches or small pits. All of the above may occur on a surveyed grid; and
- **geophysics** uses a range of techniques to look for anomalous physical properties indicating structures or mineralisation not visible at the surface. The geophysical properties being assessed include magnetism, electrical conductivity, resistivity or capacitance; gravity; natural radioactivity or seismic properties. Surveys can be airborne for regional surveys, or ground based. The impact of ground-based survey is generally very low, but will vary depending upon the extent of grid and track development required.

The above methods are broadscale in scope and provide information that builds up a picture of where mineralisation is most likely to occur. The most economical way to assess in detail the possible presence of an ore body is by drilling, which may be supplemented by bulk sampling:

- **drilling** is usually carried out by truck-mounted equipment to yield samples for mineralogical, chemical or metallurgical analysis. Drill holes are usually around 10 cm in diameter. Follow-up-drilling may be required should earlier drilling show positive results. The impact of drilling on the environment depends on the openness of the vegetation and the topography. Usually, drilling rigs are able to be manoeuvred around trees or the drill hole relocated to avoid disturbance of trees. A small level pad, typically around 6 metres square, may need to be constructed to accommodate the drilling rig; and
- **bulk sampling** gives another level of confidence in the drilling results particularly when gold is not evenly dispersed throughout the ore and coarsely grained. The ‘nugget-effect’ can give rise to misleading reserve assessments and large samples are needed to overcome it. Bulk samples are usually excavated from a site, typically less than 5 metres deep and 10 metres square.

Rehabilitation of areas disturbed by exploration is required in Victoria.

Compared with exploration, mining generally covers relatively small areas, involves greater disturbance to the land surface in the immediate area of the mine, and may leave changed landforms when mining is finished. Mining is generally seen as posing greater difficulties in terms of compatibility with other land uses.

Many potential environmental effects of mining activities can be eliminated or mitigated, though at a cost to the mining company. Relatively limited areas of land are disturbed by the operation of a mine. However, off-site impacts such as water pollution may represent a potential threat to the environment and must be carefully managed. This can be controlled by using techniques such as impoundment and evaporation of tailings, sedimentation, filtration and pH neutralisation. Rehabilitation of mine sites is mandatory in Victoria. Modern site rehabilitation, at the completion of operations, can restore many of the features of the landscape that existed before mining began, substantially replacing and assisting the re-establishment of vegetation and reducing the potential for pollution from the former mine site.

All mining projects in Victoria require approval under local government planning controls or by preparation of an Environmental Effects Statement. Both processes provide for public input and independent scrutiny of projects. Detailed assessments of impacts on natural values

are a routine aspect of mining approvals. Such assessments may include impacts on flora and fauna, water supply, catchment management and public safety.

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Appendixes

Appendix A Methodology for assessment of potential (undiscovered) mineral resources

The mineral potential of the study areas has been assessed by determining the types of mineral deposits likely to be found under the geological conditions known or believed to exist there. The general methodology used, described below, was developed by the United States Geological Survey (USGS), and has been used successfully for mineral resource assessments of forest areas in North America and elsewhere. The qualitative methodology for the assessment of potential mineral resources is described by Marsh, Kropschot and Dickinson (1984), Taylor and Steven (1983), and by Dewitt *et al.* (1986).

The qualitative method is essentially the first step of the ‘Three Step Method’ used for quantitative assessments of potential mineral resources that was thoroughly evaluated and subsequently supported by a panel of experts in 1993 (Harris & Rieber 1993). There has been no quantitative assessment in the Gippsland region.

An assessment of the potential mineral resources of a region combines knowledge of the region’s geology, geophysics, geochemistry, mineral deposits and occurrences with current theories of mineral deposit genesis and results of mineral exploration. The assessment process requires a study of available geoscientific data — for a region to small area, as required — to determine the history of geological processes and environments. Geological environments judged to have characteristics known to be associated with specific types of mineral deposits are then identified. In particular the assessment draws on regional and local characteristics of mineral deposit models to establish whether or not specific types of mineral deposits are likely to occur.

The mineral deposit models used in this assessment are generally those published by Cox and Singer (1986). These mineral deposit models are the systematic arrangements of information describing the essential attributes (properties) of groups or classes of mineral deposits. The models used are empirical (descriptive), the various attributes being recognised as essential even though their relationships are unknown. Each model encapsulates the common features of a group of deposits, as these are known from deposits around the world, and is constructed (as far as possible) to be independent of site-specific attributes not common to the group. The value of these models lies in the ability to apply what is known about a group of significant mineral deposits to the known geological environment of the area being assessed.

The assessment takes into account all of the features of the deposit models and whether these features can be recognised in the geoscientific data available for the area being assessed. Local and regional-scale features provide evidence as to whether the geological environment is conducive to, or permissive of, the formation of a given deposit type.

There are probably at least 70 styles of mineral deposits of economic or potential economic significance in Australia. These have distinct features and have formed in different ways. It is not be feasible to apply models for all of these deposit classes systematically in each study area. Only the deposit types judged to be most likely to constitute economically significant resources in each area have been assessed in any detail. Where necessary, variations on USGS deposit models (Cox & Singer 1986) can be made to better fit regional circumstances.

Qualitatively assessed potential resources

A qualitative assessment of the potential resources of an area is an estimate of the likelihood of occurrence of mineral deposits which may be of sufficient size and grade to constitute a mineral resource. The qualitative assessment methodology is described by Marsh *et al.* (1984), Taylor and Steven (1983), and Dewitt *et al.* (1986).

The mineral potential of an area is assessed for specific types of mineral deposits. For each type of deposit considered in a given area, the mineral potential is ranked in qualitative terms as 'high', 'moderate', 'low', 'no' or 'unknown', based upon professional judgements of geoscientists involved in the assessment. A qualitative mineral potential assessment is not a measure of the resources themselves. It cannot be classified according to the two dimensional ('McKelvey') diagram used for identified resources. For this reason the qualitatively assessed potential resources are shown in a separate box (Figure 3). The rankings are defined as follows.

- **H**—An area is considered to have a high mineral resource potential if the geological, geophysical or geochemical evidence indicate a high likelihood that mineral concentration has taken place and that there is a strong possibility of specific type(s) of mineral deposit(s) being present. The area has characteristics which give strong evidence for the presence of specific types of mineral deposits. The assignment of high resource potential does not require that the specific mineral deposits types have already been identified in the area being assessed.
- **M**—An area is considered to have a moderate mineral resource potential if the available evidence indicates that there is a reasonable possibility of specific type(s) of mineral deposit(s) being present. There may or may not be evidence of mineral occurrences or deposits. The characteristics for the presence of specific types of mineral deposits are less clear.
- **L**—An area is considered to have a low mineral resource potential if there is a low possibility of specific types of mineral deposit(s) being present. Geological, geophysical and geochemical characteristics in such areas indicate that mineral concentrations are unlikely, and evidence for specific mineral deposit models is lacking. The assignment of low potential requires positive knowledge and cannot be used as a valid description for areas where adequate data are lacking.
- **N**—The term 'no' mineral resource potential can be used for specified types of mineral deposits in areas where there is a detailed understanding of the geological environment and geoscientific evidence indicates that such deposits are not present.
- **U**—If there are insufficient data to classify the areas as having high, moderate, low or no potential, then the mineral resource potential is unknown.

To reflect the differing amount of information available, the assessment of mineral potential is also categorised according to levels of certainty, denoted by letters A to D (Figure 3).

- **A**—The available data are not adequate to determine the level of mineral resource potential. This level is used with an assignment of unknown mineral resource potential.
- **B**—The available data are adequate to suggest the geological environment and the level of mineral resource potential, but either the evidence is insufficient to establish precisely the likelihood of resource occurrence or the occurrence and/or genetic models are not well enough known for predictive resource assessment.
- **C**—The available data give a good indication of the geological environment and the level of mineral resource potential.

- **D**—The available data clearly define the geological environment and the level of mineral resource potential.

Appendix B Mineral resource assessment and mineral deposit models

Au1: Slate-belt gold deposits

(Model 36A of Cox and Singer, 1986)

Model description

Description of the model after Byron R. Berger

Approximate synonyms: Mesothermal quartz veins, Mother Lode veins, Turbidite-hosted gold veins, Slate belt gold veins, low sulphide gold-quartz veins, Lode gold veins.

Description: Gold in quartz veins and silicified lode structures, mainly in regionally metamorphosed rocks.

General references: Forde and Bell (1994); Hodgson, Love and Hamilton (1993)

Geological environment

Rock types: Greenstone belts; oceanic metasediments: regionally metamorphosed volcanic rocks, greywacke, chert, shale, and quartzite, especially turbidite-deposited sequences. Alpine gabbro and serpentine. Late granitic batholiths.

Age range: Precambrian to Tertiary.

Depositional environment: Continental margin mobile belts, accreted margins. Veins age pre to post-metamorphic and locally cut granitic rocks.

Tectonic setting(s): Fault and joint systems produced by regional compression.

Associated deposit types: Placer Au-PGE, Homestake gold. Fosterville-Nagambie style gold (stockworks).

Deposit description

Mineralogy: Quartz ± carbonates ± native gold ± arsenopyrite ± pyrite ± galena ± sphalerite ± chalcopyrite ± pyrrhotite ± sericite ± rutile. Locally tellurides ± scheelite ± bismuth ± tetrahedrite ± stibnite ± molybdenite ± fluorite. Gold-bearing quartz is greyish or bluish in many instances because of fine-grained sulphides. Carbonates of Ca, Mg, and Fe abundant.

Texture/structure: Saddle reefs, ribbon quartz, breccias, open-space filling textures commonly destroyed by vein deformation.

Alteration: Quartz + siderite and (or) ankerite ± albite in veins with possible halo of carbonate alteration. Chromian mica ± dolomite ± talc ± siderite in areas of ultramafic rocks. Sericite ± disseminated arsenopyrite ± rutile in granitic rocks.

Ore controls: Veins occur along regional high-angle faults, joint sets. Best deposits overall in areas with greenstone. High-grade ore shoots locally at metasediment-serpentine contacts. Disseminated ore bodies where veins cut granitic rocks. Carbonaceous shales and may be

important. Competency contrasts, e.g. shale/sandstone contacts and intrusive contacts may be important.

Weathering: Abundant quartz chips in soil. Red limonitic soil zones. Gold may be recovered from soil by panning.

Geochemical signature: Gold best pathfinder in general; As, Ag, Pb, Zn, Cu may be useful.

Geophysical signature: Poorly defined generally, but magnetics may define important structures.

Examples

- Bendigo Goldfield, Australia, Victoria (Sharpe & MacGeehan 1990)
- Ballarat East Gold Deposits, Australia, Victoria (d'Auvergne 1990)
- Mother Lode, US, California (Knopf 1929)
- Goldfields of Nova Scotia, Canada, Nova Scotia (Malcolm 1929)

Known deposits and mineral occurrences in the Gippsland region

The area hosts a large number of gold prospects and deposits which form part of three major gold provinces in Victoria (from west to east): Walhalla-Woodpoint sub-province of the Melbourne Gold Province, Harrietville Dargo Gold Province and Benambra Gold Province. In all three provinces four major quartz reef types are recognised (Kenny 1953 cited in Ramsay & Willman 1988):

- fissure reefs which are generally lenticular and discordant to bedding and occupy fissure planes (e.g. Mons Meg, Monarch Samabs);
- bedded reefs which are generally laminated and parallel to bedding planes, with laminations separated by thin films of medsedimentaries (e.g. Rose Thistle and Shamrock);
- reefs associated with dykes. They either truncate the dyke or occur sub-parallel to one wall of the dyke (e.g. Red Robin, Big Gun Extended);
- spurry reefs are tension gashes, irregular quartz fissures and stockworks (e.g. Crescent Mine).

Using the classification of gold deposits by Ramsay and Willman (1988), the following types of gold deposits can be recognised in the area: sediment/metasediment-hosted, granitoid hosted/related; and dyke hosted/affiliated. Quartz veins are predominantly hosted by Middle to Upper Ordovician metasediments (lower greenschist facies metamorphism). Locally Cambrian/Ordovician Bethanga Gneiss in the Benambran Gold Provinces also hosts mineralised quartz reefs.

Geological studies in the area and other gold fields in Victoria fail to recognise any single geological factor controlling mineralisation. The factors and the age of mineralisation seem to vary from area to area with a combination of two or more factors (structural, lithological, magmatic, geochemical) becoming important in different areas. In addition to the well-documented structural control (faults, fissure, dialational jogs, and fold hinges) it is possible that some form of lithological control was important in some areas. For instance, in the Benambra Gold Province greasy, carbonaceous pyritic slate has been described as an ideal host of mineralisation. Similarly in the Ballarat East goldfield it is suggested that

mineralisation is often localised by the presence of ‘indicator beds’ (O’Shea *et al.* 1994). The greenschist facies metamorphism might also be an important factor in the formation of gold mineralisation. In some gold provinces in Victoria which include some gold fields in the region the presence of dyke swarms is an important ore-localising factor. Dykes in the southern extension of the Woods Point Dyke Swarm in the region host rich gold mineralisation.

Gold deposits in the region belong to three gold provinces: Melbourne, Harrietteville-Dargo and Benambra. Gold mineralisation in the Melbourne province the most significant deposits (such as Cohen’s Reef and Walhalla) are associated with Middle Devonian dyke swarm intruding into Lower Devonian sediments deformed and metamorphosed to lower greenschist facies during Tabberabberan orogeny. The dykes are primarily of dioritic and lamprophyric composition and are altered and sheared close to the zones of mineralisation. Within the dykes Edwards (cited in Ramsay & Willman, 1988) recorded reefs within or along the walls of dykes, and reefs in fault planes spatially associated with dykes (e.g. Cohen). However there are reefs (bedded and fault-related) and spurs and stockwork mineralisation with no direct spatial association with dykes.

Gold mineralisation in the Harrietteville-Dargo province is structurally defined by a corridor extending from the Mount Wellington Fault Zone (now Governor Fault) in the west, to the Kiewa Fault in the east (Gray 1988 cited in Maher *et al.* 1997). Most veins (75 per cent) lie within a structural zone defined by the Wonnangatta Fault in the west and the Ensay Fault in the east with Kiewa fault playing the role of the major regional control of mineralisation. Kiewa fault is an extension of the Kancoona Fault (Maher *et al.* 1997), which is reported to control gold mineralisation in the northern part of the Harrietteville-Dargo and Benambra provinces. Mineralisation in the Harrietteville-Dargo provinces is hosted by Ordovician turbidites, Devonian granites and their hornfelsic halos. Mineralisation in the Gladstone gold field is hosted by Upper Devonian sandstones of the Moreka Glen Formation. In the Hunted Stream and Shady Creek gold fields, although mineralisation is located with Ordovician turbidites, there are several diorite dykes present in close proximity to the mineralised veins (Maher *et al.* 1996).

In the Benambran gold province mineralisation is hosted in the Omeo Metamorphic Complex, turbidites of the Hotham Group and granitoids. Some mineralisation is also found in the Pinnak Sandstone of Ordovician age (Maher *et al.* 1996).

Recent geophysical studies in three gold fields (Stawell, St Arnaud and Beaufort) has revealed that they share two common characteristics. All are hosted within weakly but more distinctly magnetic units than the surrounding rock, and all lie about two kilometres or less from the edge of a nonmagnetic granite, possibly a felsic I-type intrusion (Moore 1996). In the Gippsland region a similar spatial association is also observed. Mineralised veins are often hosted by granites themselves and in the surrounding thermal halo.

Spatial analysis of the distribution of primary mineralisation in the region shows that a 60 kilometre corridor between the Wonnangatta Fault in the west and the Ensay Fault in the east hosts more than 75 per cent of known occurrences; 15 per cent of occurrences are hosted by Silurian and/or Devonian granitoids and almost 50 per cent are within five kilometres of the granitoids.

Generally, slate-belt gold mineralisation is associated with Middle-Late Devonian Tabberabberan deformation and metamorphism. However, recent studies in the Tabberabberan zone (Benambran gold province) show that mineralisation is of Middle Silurian-Early Devonian (late Benambran-Bindian) age (Morand & Gray 1991 cited in Oppy *et al.* 1995). A more accurate date is estimated in areas where gold veins cut dyke swarms.

For example dykes in the Woods Point Dyke Swarm are dated to have been emplaced in around 380 Ma. (Middle Devonian) which means that gold mineralising event in dyke-related environment was post Middle Devonian.

Assessment criteria

1. Distribution of the Ordovician, Silurian and Devonian turbidites and their metamorphic equivalents.
2. Presence dyke swarms.
3. Presence of major north-northwest trending fault zones.
4. Presence of Silurian and Devonian granitoids (particularly I-type).
5. Presence of primary and/or alluvial gold deposits and prospects.

Assessment

Tract Au1a/H/B-C

The tract is delineated based on the two structural corridors around

- the Kiewa Fault, which hosts bulk of the known slate-belt gold occurrences in the area; and
- the Woods Point Dyke Swarm that hosts the Walhalla – Woods Point gold subprovince.

Both these corridors are marked by prominent fault zones which are known to have played a role in controlling gold mineralisation. The corridors contain:

- Ordovician, Silurian, Siluro-Devonian and Devonian turbidites and their metamorphic equivalents;
- Dyke swarms (Woods Point; possible extensions of Mitta-Mitta, and Tintaldra-Cudgewa, Walwa, and other smaller dyke swarms in the Benambra gold province); and
- Silurian and Devonian granites within a corridor defined by the Wonnangatta Fault in the west and the Ensay Fault in the east.

The tract contains most of the known primary gold occurrences and a large number of alluvial deposits.

The tract contain turbiditic rocks, dyke swarms, major ore localising regional structures, and numerous primary and alluvial occurrences of gold. Mineral potential of the tract is assessed as high with a certainty level of C in areas of known dyke swarms and a certainty level of B for areas where dykes are interpreted based on the high resolution aeromagnetics.

Tract Au1b/M-H/B

The tract includes areas that contain the favourable host rocks described in the preceding tract but located outside the two structural corridors. The tract is known to host several primary and placer gold occurrences.

Mineral potential of the tract is assessed to be moderate to high with a certainty level of B.

Tract Au1c/M/B

The tract includes windows of Ordovician (Mount Easton Shales), Silurian and Devonian sedimentary rocks in the southern part of the Latrobe Valley. These are favourable host rocks for the mineralisation and host a few occurrences of slate belt gold. The tract is assigned moderate potential (certainty level of B) because strike direction of major faults in the tract is north east, which is different from the meridional and northwest direction in the three major gold provinces in the area. In addition known outcrops of Silurian and Devonian granitoids are more than 15 kilometres away.

Tract Au1d/L-M/B

The tract contains area occupied by Silurian I and S-type granitoids outside the structural corridor. The granitoids contain a few occurrences of slate belt gold. In the Benambra gold province some granitoids are intruded by dykes. Granitoids often host some slate belt gold mineralisation but they are not as good hosts as turbidites.

Mineral potential of the tract is thus assessed to be low to moderate with a certainty level of B.

Economic significance

The slate belt type of gold deposits are one of the largest type of gold deposits and are an important source of gold and silver. According to the grade/tonnage models for the low-sulphide gold-quartz veins (Cox & Singer 1986) 90 per cent of these deposits contain at least 0.001 million tonnes of ore; 50 per cent contain at least 0.03 million tonnes and 10 per cent contain at least 0.91 million tonnes. In 90 per cent of these deposits contain at least 6 grams per tonne gold; 50 per cent contain at least 15 grams per tonne gold and 10 per cent contain 43 grams per tonne gold.

Au2: Disseminated gold deposits

Model description

Approximate synonyms: Sandstone-hosted gold deposits. Low-grade disseminated gold deposits, Stockwork gold deposits.

Description: Disseminated gold in altered rocks in proximity to known slate-belt gold veins.

General references: Montoya *et al.* (1995); Kwak and Roberts (1996).

Geological environment

Rock types: Greenstone belts; oceanic metasediments: regionally metamorphosed volcanic rocks, greywacke, chert, shale, and quartzite, esp. turbidite-deposited sequences. Alpine gabbro and serpentine. Late granitic batholiths and swarms of dykes.

Age range: Precambrian to Tertiary. In Victoria most deposits are of Palaeozoic age.

Depositional environment: Continental margin mobile belts, accreted margins. Veins age pre to post-metamorphic and locally cut granitic rocks.

Tectonic setting(s): Fault and joint systems produced by regional compression.

Associated deposit types: Slate-belt gold veins, Placer Au-PGE, Homestake gold.

Deposit description

Mineralogy: Mineral composition similar to that in typical state-belt gold deposits. Mineralisation represented by sulphides (pyrite, arsenopyrite, chalcopyrite, sphalerite, stibnite and gold in altered rocks containing carbonates, quartz, sericite and chlorite. In some deposits sulphides form spheroids or framboids with anomalously high concentration of zinc, copper, nickel, gold, antimony, lead, arsenic and lead.

Texture/structure: Stockwork and zones of dissemination in jogs in shears.

Alteration: Assemblages containing carbonates (calcite, siderite, sideroplesite, and ankerite), phengitic sericite, ripidolitic chlorite, and sulphides (pyrite, chalcopyrite, auriferous arsenopyrite and sphalerite) occurring within about 100–150 metres of major textures. Silicification is either mild or absent.

Ore controls: Mineralised zones along fold axes, and fault and shear zones. Individual deposits in jogs created by shears obliquely cross previously-formed anticlines and synclines. Some occur near ‘chokes’ in structures. For some deposits presence of dykes is a characteristic feature.

Weathering: Limonitic zones over primary sulphide mineralisation. However gold concentration is lower than in primary mineralisation.

Geochemical signature: Gold best pathfinder in general; As, Ag, Pb, Zn, Cu may be useful.

Geophysical signature:

Examples

- Nagambie, Australia, Victoria (Gilles 1990)
- Fosterville, Australia, Victoria (McConachy & Swensson 1990)
- Peru (Montoya *et al.* 1995)

Known deposits and mineral occurrences in the region

Although haloes of disseminated mineralisation in Victoria are known to be associated with major slate-belt vein deposits, they have acquired economic importance only recently because of the possibility of their mining by small-scale, heap-leaching techniques. Within the region there are no major deposits of this type.

A number of important known occurrences of this type occur within the 15 kilometre buffer zone. The most significant of these is the Morning Star gold mine. Mineralisation in the Woods Point-Jamieson goldfield is associated with Middle Devonian dyke swarm intruding into Lower Devonian sediments deformed and metamorphosed to lower greenschist facies during Tabberabberan orogeny. The dykes are primarily of dioritic and lamprophyric composition and are altered and sheared close to the zones of mineralisation. Recent exploration has revealed disseminated mineralisation in the vicinity of ladder veins where the dyke is bleached because of alteration.

A number of well-known deposits of this type occur outside the region. The most well known of these are Fosterville and Nagambie in the Bendigo-Ballarat Gold Zone. Although these deposits have been studied in some detail no clear single geological factor appears to control

this type of mineralisation. Important geological factors include (Kwak & Roberts 1996): structural (shear and fault zones in particular jogs where shear obliquely cross previously formed folds), lithological (relatively porous sandstone and/or interbedded black shale, and magmatic (presence of K-feldspar-quartz porphyritic dykes).

In the Nagambie gold deposit, mineralisation is hosted by a thick sequence of Silurian-Devonian turbidites protruding through flat lying Quaternary sediments of the Shepparton Formation. Economically significant mineralisation occurs along the crest of an anticline. Mineralisation is in the form of quartz veins, stringers and stockworks (Gillies 1990).

Some gold occurrences in the Chiltern-Rutherglen gold field (VicRFASC 1997) are reported to have features similar to sandstone-hosted disseminated gold deposits with gold reported to be occurring in sandstone and shale pebbles in leads and outcrops. Locally economic grade, stockwork mineralisation was mined at shallow levels of mineralised quartz reefs (e.g. Magenta Reef, Maher et al. 1997).

Assessment criteria

1. Tracts with mineral potential for slate belt gold mineralisation.
2. Distribution of the Ordovician, Silurian and Devonian turbidites and their metamorphic equivalents.
3. Presence of dykes
4. Presence of fault zones.
5. Presence of slate-belt gold veins.
6. Presence of bleached and altered rocks.
7. Presence of alluvial and deep lead gold deposits and prospects.

Assessment

Tract Au2a/M-H/B-C

This tract is identical to the high potential tract (tract Au1a/H/B-C) for slate belt gold deposits and contains the most favourable environment for the emplacement of slate-belt gold mineralisation. The tract is defined by two structural corridors around:

- the Kiewa Fault, which hosts bulk of the known slate-belt gold occurrences in the area; and
- the Woods Point Dyke Swarm that hosts the Walhalla – Woods Point gold subprovince.

Both these corridors are marked by prominent fault zones which are known to have played a role in controlling gold mineralisation. The corridors contain:

- Ordovician, Silurian, Siluro-Devonian and Devonian turbidites and their metamorphic equivalents; and
- Dyke swarms (Woods Point; possible extensions of Mitta-Mitta, and Tintaldra-Cudgewa, Walwa, and other smaller dyke swarms in the Benambra gold province).

Silurian and Devonian granites within a corridor defined by the Wonnangatta Fault in the west and the Ensay Fault in the east.

The presence of slate belt gold occurrences and the fact that it has a high potential for the presence of more deposits of this type indicates that the tract has a potential for disseminated gold deposits.

Mineral potential for disseminated gold deposits in the tract is assessed to be moderate to high with a certainty level of B to C.

Tract Au2b/M/B

The tract is identical to the Au1b/M-H/B tract for slate belt gold deposits. It includes areas that contain favourable host rocks described in the preceding tract but located outside the two structural corridors. The tract is known to host several primary and placer gold occurrences.

Mineral potential of the tract is assessed to be moderate potential with a certainty level of B.

Tract Au2c/L-M/B

The tract is identical to the tract Au1c/M/B for the slate belt gold deposits.

It includes windows of Ordovician (Mount Easton Shales), Silurian and Devonian sedimentary rocks in the southern part of the Latrobe Valley. These are favourable host rocks for the mineralisation and host a few occurrences of slate belt gold. The tract is assigned low to moderate potential (certainty level of B) because it has been assessed to have a moderate potential for slate belt gold deposits. As previously mentioned, the strike direction of major faults in the tract is north east, which is different from the meridional and north west direction in the three major gold provinces in the area. In addition, known outcrops of Silurian and Devonian granitoids are more than 15 kilometres away.

Tract Au2d/L/B

The tract is identical to the Low to moderate potential tract (Au1d/L-M/B) for slate-belt gold deposits. Main rocks in the tract are Silurian and Devonian granitoids which are known to host several occurrences of primary slate-belt gold. As the potential for slate-belt gold in the tract has been assessed to be low to moderate it is suggested that the tract has a low potential for disseminated gold deposits with a certainty level of B.

Au3: Epithermal gold-silver deposits

(Model 25B of Cox and Singer, 1986)

Model description

Description of the model after Dan L. Mosier, Takeo Sato, Norman J Page, Donald A. Singer, and Byron R. Berger

Approximate synonym: Epithermal gold (quartz-adularia) alkali-chloride-type, polymetallic veins.

Description: Galena, sphalerite, chalcopryrite, sulfosalts, + tellurides + gold in quartz-carbonate veins hosted by felsic to intermediate volcanics. Older miogeosynclinal evaporites or rocks with trapped seawater are associated with these deposits.

General references: Buchanan (1980), Berger and Bethke (1985), White and Hedenquist (1990), Henley (1991).

Geological environment

Rock types: Host rocks are andesite, dacite, quartz latite, rhyodacite, rhyolite, and associated sedimentary rocks. Mineralisation related to calc-alkaline or bimodal volcanism.

Textures: Porphyritic.

Age range: Mainly Tertiary (most are 29–4 Ma.).

Depositional environment: Bimodal and calc-alkaline volcanism. Deposits related to sources of saline fluids in prevolcanic basement such as evaporites or rocks with entrapped seawater.

Tectonic setting(s): Through-going fractures systems; major normal faults, fractures related to doming, ring fracture zones, joints associated with calderas. Underlying or nearby older rocks of continental shelf with evaporite basins, or island arcs that are rapidly uplifted.

Associated deposit types: Placer gold, epithermal quartz alunite Au, polymetallic replacement, Porphyry Cu-Au.

Deposit description

Mineralogy: Galena + sphalerite + chalcopyrite + copper sulfosalts + silver sulfosalts ± gold ± tellurides ± bornite ± arsenopyrite. Gangue minerals are quartz + chlorite ± calcite + pyrite + rhodoarsenite + barite ± fluorite ± siderite ± ankerite ± sericite ± adularia ± kaolinite. Specular hematite and alunite may be present.

Texture/structure: Banded veins, open space filling, lamellar quartz, stockworks, colloform textures.

Alteration: Top to bottom: quartz ± kaolinite + montmorillonite ± zeolites ± barite ± calcite; quartz + illite; quartz + adularia ± illite; quartz + chlorite; presence of adularia is variable.

Ore controls: Through-going or anastomosing fracture systems. High-grade shoots where vein changes strike or dip and at intersections of veins. Hanging-wall fractures are particularly favourable.

Weathering: Bleached country rock, goethite, jarosite, alunite--supergene processes often important factor in increasing grade of deposit.

Geochemical signature: Higher in system Au + As + Sb + Hg; Au + Ag + Pb + Zn + Cu; Ag + Pb + Zn, Cu + Pb + Zn. Base metals generally higher grade in deposits with silver. W + Bi may be present.

Geophysical signatures:

Examples

- Pajingo, Australia, Queensland (Bobis *et al.* 1996)
- Creede, US, Colorado (Steven & Eaton 1975; Barton *et al.* 1977)
- Pachuca, Mexico (Geyne *et al.* 1963)
- Toyoha, Japan (Yajima & Ohta 1979)

Known deposits and mineral occurrences in the Gippsland region

Numerous occurrences of this epithermal mineralisation are associated with the Lower Devonian Snowy River Volcanics and are confined to the Buchan Rift. The most significant of these are: Glen Shiel Silver mine, W-Tree Creek prospect, Pyramid Mountain prospect, Halls Peninsula prospect, El prospect and Roger River prospect.

Epithermal mineralisation in these prospects is represented by silicified breccia zones, zones of quartz veins and associated stockworks, zones of chalcedony and massive quartz veins in rhyolitic to rhyodacitic volcanics. Quartz veins show typical epithermal textures such as chalcedony, colloform, crustiform, banded, comb and lattice or bladed. The veins often contain disseminated pyrite, with minor barite, specular and micaceous haematite, chalcopryrite and traces of galena, native silver and a silver sulphide. Apart from silicification the host rocks show propylitic, phyllic and argillic alterations. Fluid inclusion studies in the W-Tree prospect suggest temperatures of formation between 135° and 180°C from fluid with relatively high salinities of up to 14.3 weight per cent equivalent, which may reflect a magmatic component to the mineralisation.

In the Mount Elizabeth area alterations similar to porphyry and epithermal systems have also been recognised. Here the mineralisation is thought to be related to a caldera structure occupied by the Snowy River Volcanics and the I-type Tambo Crossing granodiorite.

Several occurrences of epithermal gold-silver deposits are also reported in the north-northwest trending Barkley River Greenstone belt. These occurrences are reported to show features characteristic of epithermal mineralisation. The most important of these are the Hill 700–800 prospects (Turner 1996), which are located within the 15 kilometre buffer zone of the region. These prospects and anomalies are hosted by Cambrian andesitic and rhyolitic volcanics. Mineralisation at Hill 800 is of a disseminated to massive replacement style with no discrete veins. At Hill 800 silicification is seen as chert lenses or clasts, disseminations and quartz veining is uncommon, and is post mineralisation (Turner 1996).

The Rhyolite Creek prospect in the same area is known to have several pervasive argillic alteration zones characterised by the presence of pyrite and pyrophyllite. Mineralisation is in the form of stockwork veins which are flattened by shear strain. A second type of mineralisation comprises lenses of massive sulphide hosted by a siliceous breccia within volcanoclastic sediments. The prospect is thought to be analogous to other deposits at Temora, Peak Hill and near Junee in New South Wales all of which are considered to be formed from high sulphidation, high temperature, acid and probably magmatically derived fluids (VandenBerg *et al.* 1995 cited in Turner 1996).

Assessment criteria

1. Distribution of intrusive/extrusive complexes represents a predominantly subaerial complex of volcanic and volcanoclastics of silicic to mafic composition.
2. Presence of favourable structures such as caldera with ring fractures and zones of brecciation.
3. Presence of alterations such as: silicification, propylitic, chloritic, sericitic and argillic.
4. Presence of mineral prospects having features similar to epithermal precious-metal deposits.

Assessment

Tract: Au3a/H/B-C

The tract contains areas favourable for two types of epithermal gold-silver deposits. One of them is defined by Cambrian volcanics that form the north-northwest trending Barkly River Greenstone Belt in the western part of the region. The tract includes small areas where the presence of greenstone rocks is deduced from the interpretation high-resolution aeromagnetics. The belt hosts a number of known occurrences which have features similar to epithermal gold-silver deposits (Turner 1996).

The second type of epithermal gold-silver deposits are related to the volcanic, volcanoclastic and sedimentary rocks of the Snowy River Volcanics, exposed mainly within the Buchan Rift. The tract also includes the Mount Elizabeth Caldera that contains rocks of the Snowy River Volcanics and Devonian granodioritic bodies.

Lower Devonian Snowy River Volcanics (SRV) comprise a complex sequence of ignimbritic rhyodacites and rhyolites with minor andesite, rhyolite lava and breccia, tuff, conglomerate, siltstone, tuffaceous sandstone, and several intercalation of marine sandstone and siltstone.

The tract hosts several prospects with epithermal style of gold-silver mineralisation. Vein quartz in them shows textures which are diagnostic of epithermal systems, most significant of which are the chalcedony, colloform-crustiform, banded and lattice or bladed textures. These prospects also show typical, for epithermal systems, wall-rock alterations such as, silicification, phyllic, argillic and propylitic.

Although most significant epithermal deposits are of Tertiary age, mineral exploration in the last two decades has revealed equally significant mineralisation associated with Palaeozoic epithermal systems. Some of the most prominent of these are: Pajingo, Wirrilie and the Golden Plateau deposits in Queensland.

Generally mineralisation in epithermal systems is formed at shallow depths and do not extend more than 500 metres vertically. Hence many epithermal systems of Palaeozoic age are often eroded. However, in the tract the Snowy River Volcanics are protected from erosion within the downfaulted Buchan Rift and there are indications that not all epithermal systems have been eroded away. The strongest supporting factor is the presence of quartz with chalcedony and lattice or bladed textures. Quartz with these textures is known to occur in the upper parts of epithermal systems (Gyoui *et al.* 1995). The presence of argillic and clay alterations also indicates that the epithermal systems in the Buchan Rift were not deeply eroded.

In the Mount Elizabeth Caldera, volcanics and volcanoclastics unconformably overlie the Silurian Tambo Crossing Tonalite and are intruded by the I-type St. Patricks Creek Granite. The rocks show silicification and disseminated pyrite with patchy chlorite and haematite. The complex is marked by numerous ring and radial fractures (Maher *et al.* 1996). The boundary of the caldera is interpreted from aeromagnetic data.

Thus based on the available information it is concluded that the tract has a high potential for epithermal mineralisation with a certainty level of C. Areas within the interpreted boundary of the caldera are assigned a lower level of certainty (B).

Generally epithermal systems which form quartz-adularia type of mineralisation also generate acid-sulphate type of gold-silver mineralisation. This mineralisation is usually confined to the uppermost parts of the system. Hence it is possible that locally the tract contains this type of mineralisation.

Tract: Au3b/M/B

This tract includes Devonian S-type subaerial felsic volcanics and volcanoclastics such as the Sheevers Spur Rhyodacite.

Although no mineral occurrences of epithermal gold-silver mineralisation have been recorded within the areas of Devonian complexes the presence of subareal felsic volcanics suggests that epithermal style of hydrothermal system could have been generated by and around them.

Hence the tract is interpreted to have a moderate potential for epithermal gold-silver deposits with a certainty level of B.

Generally epithermal systems which form quartz-adularia type of mineralisation also generate acid-sulphate type of gold-silver mineralisation. This mineralisation is usually confined to the uppermost parts of the system. Hence it is possible that locally the tract contains this type of mineralisation.

Economic significance

Epithermal gold-silver deposits are important sources for gold and silver. Grade/tonnage model for deposits of this type (Cox & Singer 1986) indicates that 90 per cent of deposits contain more than 0.065 million tonnes of ore, 50 per cent more than 0.77 million tonnes and 10 per cent contain more than 9.1 million tonnes. In 90 per cent of these deposits ores have at least 2.0 grams per tonnes gold and 10 grams per tonne silver. The ores in 50 per cent of these deposits have at least 7.5 grams per tonne gold and 110 grams per tonne silver. In 10 per cent of these deposits the ores have at least 27 grams per tonne gold and 1 300 grams per tonne silver.

Au4: Placer gold

(Model 39A of Cox and Singer, 1986)

Model description

Modified after Warren E. Yeend

Approximate synonym:

Description: Elemental gold as grains and (rarely) nuggets in gravel, sand, silt, and clay, and their consolidated equivalents, in alluvial, beach, eolian, and (rarely) glacial deposits.

General references: Boyle (1979), Wells (1973), Lindgren (1911).

Geological environment

Rock types: Alluvial gravel and conglomerate, usually with white quartz clasts. Sand and sandstone of secondary importance.

Textures: Coarse clastic.

Age range: Cainozoic. Older deposits are known but their preservation is uncommon.

Depositional environment: High-energy alluvial where gradients flatten and river velocities lessen, as at the inside of meanders, below rapids and falls, beneath boulders, and in

vegetation mats. Winnowing action of surf caused Au concentrations in raised, present, and submerged beaches.

Tectonic setting(s): Tertiary conglomerates along major fault zones, shield areas where erosion has proceeded for a long time producing multicycle sediments; high-level terrace gravels.

Associated deposit types: Black sands (magnetite, ilmenite, areaomite); Platinum group elements, yellow sands (zircon, monazite). Au placers commonly derive from various Au vein-type deposits but also other gold deposits, e.g. porphyry copper-gold, gold skarn, massive sulphide deposits and replacement deposits.

Deposit description

Mineralogy: Au, commonly with attached quartz or limonite, rarely attached to sulphides and other gangue minerals. Associated with quartz and heavy minerals, which may include: rutile, ilmenite, areaomite, magnetite, limonite, pyrite, zircon, monazite, tourmaline, cassiterite, platinum-iron alloys and osmium-iridium alloys.

Texture/structure: Usually flattened with rounded edges, also flaky or flour gold (extremely fine grained); rarely angular and irregular ('crystalline'), very rarely equidimensional nuggets.

Ore controls: Highest Au values at base of gravel deposits in various gold 'traps' such as natural riffles in floor of river or stream, fractured bedrock, slate, schist, phyllite, dikes, bedding planes, all structures trending transverse to direction of water flow. Au concentrations also occur within gravel deposits above clay layers that constrain the downward migration of Au particles.

Geochemical signature: Anomalous high amounts of Ag, As, Hg, Sb, Cu, Fe, S, and heavy minerals magnetite, areaomite, ilmenite, hematite, pyrite, zircon, garnet, rutile. Au nuggets have decreasing Ag content with distance from source.

Geophysical signature: Seismic methods define buried channels or deep leads.

Examples

- Sierra Nevada, US, California (Lindgren 1911, Yeend 1974)
- Victoria, Australia, Victoria (Knight 1975)

Known deposits and mineral occurrences in the Gippsland region

There are numerous localities in the region where alluvial gold was mined.

In addition to the typical placer deposits, the region is also favourable for the presence of deep and shallow lead placer gold. Deep and shallow leads are quite common elsewhere in Victoria. Deep leads are buried gold placers which formed at various times during the Cainozoic and were later buried under alluvium or basalt or both. In Victoria some leads are preserved under Eocene? Older Volcanics, some are under Pliocene-Pleistocene basalt. Most of the deep lead concentrations were formed along valleys draining inland from the main divide and were later modified during Cainozoic uplift and consequent stream rejuvenation.

Assessment criteria

1. Presence of gold-bearing source rocks.
2. Distribution of alluvial, eluvial, fluvio-glacial and lacustrine deposits.
3. Distribution of Tertiary and Quaternary sediments.
4. Distribution of alluvial gold prospects and deposits.

Assessment

Tract Au4a/L-M/B-C

Distribution of Tertiary and Quaternary sediments has been used to delineate this tract. In the Gippsland Basin, Tertiary and Quaternary rocks that are in the marginal part of the basin (within five kilometres of the basin boundary) are included.

The region hosts numerous slate-belt gold and disseminated gold deposits and occurrences which are a potential source of alluvial gold. The tract contains numerous occurrences of alluvial gold.

From the widespread distribution of primary sources of gold in the region it is concluded that the region has a low to moderate potential (with a certainty level of C for the tract outside the basin and B for the tract within the basin) for alluvial gold.

CuAu1: Porphyry copper-gold deposits

(Model 20C of Cox and Singer, 1986)

Model description

Description of the model after Dennis P. Cox

Approximate synonym: Noranda type, volcanogenic massive sulfide, felsic to intermediate volcanic type.

Description: Stockwork veinlets of chalcopyrite, bornite, and magnetite in porphyritic intrusions and coeval volcanic rocks. Ratio of Au (ppm) to Mo (per cent) is greater than 30.

General references: Sillitoe (1979, 1989)

Geological environment

Rock types: Tonalite to monzogranite; dacite, andesite flows and tuffs coeval with intrusive rocks. Also syenite, monzonite, and coeval high-K, low-Ti volcanic rocks (shoshonites).

Textures: Intrusive rocks are porphyritic with fine- to medium-grained aplitic groundmass.

Age range: Palaeozoic to Quaternary.

Depositional environment: In porphyry intruding coeval volcanic rocks. Both involved and in large-scale breccia. Porphyry bodies may be dykes. Evidence for volcanic centre; 1–2 km depth of emplacement.

Tectonic setting(s): Island-arc volcanic setting, especially waning stage of volcanic cycle. Also continental margin rift-related volcanism.

Associated deposit types: Porphyry Cu-Mo; Gold-porphyry; epithermal Ag-Au, gold placers.

Deposit description

Mineralogy: Chalcopyrite $\pm$ bornite; traces of native gold, electrum, sylvanite, and hessite. Quartz + K-feldspar + biotite + magnetite + chlorite + actinolite + anhydrite. Pyrite + sericite + clay minerals + calcite may occur in late-stage veinlets.

Texture/structure: Veinlets and disseminations.

Alteration: Quartz $\pm$ magnetite $\pm$ biotite (chlorite) $\pm$ K-feldspar $\pm$ actinolite, $\pm$ anhydrite in interior of system. Outer propylitic zone. Late quartz + pyrite + white mica $\pm$ clay may overprint early feldspar-stable alteration.

Ore controls: Veinlets and fractures of quartz, sulphides, K-feldspar magnetite, biotite, or chlorite are closely spaced. Ore zone has a bell shape centered on the volcanic-intrusive center. Highest grade ore is commonly at the level at which the stock divides into branches.

Weathering: Surface iron staining may be weak or absent if pyrite content is low in protore. Copper silicates and carbonates. Residual soils contain anomalous amounts of rutile.

Geochemical signature: Central Cu, Au, Ag; peripheral Mo. Peripheral Pb, Zn, Mn anomalies may be present if late sericite pyrite alteration is strong. Au (ppm):Mo (per cent) >30 in ore zone. Au enriched in residual soil over ore body. System may have magnetic high over intrusion surrounded by magnetic low over pyrite halo.

Geophysical signature:

Examples

- Goonumbla, Australia, New South Wales (Heithersay *et al.* 1990)
- Panguna, Papua New Guinea (Clark 1990)
- Ok Tedi, Papua New Guinea (Rush & Seegers 1990)
- Dizon, Philippines
- Dos Pobres, US, Arizona (Langton & Williams 1982)
- Copper Mountain, Canada, British Columbia (Fahrni *et al.* 1976)

Known deposits and mineral occurrences in the region

Several porphyry copper occurrences and deposits have been identified in the region. These include Dogwood and Tiger Creek. Porphyry copper type alteration has also been identified in the Mount Elizabeth Caldera Complex that comprises volcanics and volcanoclastics of the Snowy River Volcanics and the I-type Tambo Crossing granodiorite.

Stockwork and disseminated copper-molybdenum mineralisation at the Dogwood prospect is hosted by a Silurian I-type magnetic Kaerwutt Trondjemite and apophyses and by silicified crackle brecciated Ordovician turbidites (Maher *et al.* 1996). The mineralisation is blanketed by supergene chalcocite. Hypogene mineralisation is associated with sericitic alteration. The prospect also shows a significant molybdenum signature in stream sediment geochemistry.

Copper mineralisation at the Tiger Creek prospect is hosted by S-type granitoids of the Nunniong Pluton. There are several other stream sediment anomalies and copper occurrences reported from the Nunniong Pluton. Copper mineralisation at the Tiger Creek prospect is associated with sericitic, chloritic, propylitic alteration and silicification.

Assessment criteria

1. Distribution of relatively oxidised Silurian and Devonian granitoids.
2. Distribution of alkaline igneous rocks of the Mount Leinster Complex.
3. Presence of porphyry-related wall-rock alteration.
4. Strongly or moderately magnetic granitoids visible on the aeromagnetic map.
5. Presence of geochemical anomalies.
6. Presence of mineral prospects having features similar to porphyry copper deposits

Assessment

Tract: CuAu1a/M-H/B-C

The tract includes Silurian and Devonian I and S- type granitoids and the surrounding country rocks in the eastern part of the region. All granites have strong to moderate magnetic response on high resolution aeromagnetics. The surrounding country rocks (Ordovician turbidites) are included in the tract because high resolution aeromagnetics suggests that magnetic granitoids are present at shallow depths under these rocks.

The granitoids included in the tract are: Case Granite, Colquhoun Granite, Kenny Creek Granite, Mellick Munjie Granodiorite, Mollys Plain Granite, Mount McLeod Granodiorite, Nunniong Granodiorite, Saint Patricks Creek Granite and Tambo Crossing Granite.

The tract also contains several copper, copper-molybdenum, copper-molybdenum-gold and copper-gold prospects with features similar to copper porphyry systems.

Based on the above information the tract is inferred to have Moderate to High potential for porphyry copper deposits with a certainty level of C. Lower levels of certainty (B) are assigned to areas that have been included based on aeromagnetic anomalies.

Tract: CuAu1b/M/B-C

The tract includes Early Silurian and Devonian I-type, mainly mafic granitoids with a high aeromagnetic response indicative of their possible oxidised state. The granitoids included in the tract are: Anglers Rest Granite, Angora (Old Sheep Station) Granite, Barry Mountains intrusive, Castlebum, Dargo, Ensay Tonalite, Eumana (Reedy Fault) Granite, Mount Baldhead, Mount Selwyn Granite, Rileys Creek Granite and Tongio Gap Granite. Included in the tracts are two unnamed I-type Silurian granites and one Early Devonian I-type granite.

The tract also includes areas adjacent to the outcropping granitoids where aeromagnetics shows their subsurface extensions at shallow depths.

Alkaline igneous rocks of the Triassic Mount Leinster Igneous Complex are also included in the tract. Although there are no known occurrences associated with them, similar alkaline rocks in Tasmania and New South Wales are reported to host gold mineralisation.

The tract does not contain any known occurrences of copper gold mineralisation. Hence, although, the granitoids are I-type and magnetic, their potential is assessed to be moderate with a certainty level of C. Lower levels of certainty (B) are assigned to areas where the presence of granite is delineated using aeromagnetics.

Economic significance

Generally these deposits are important sources of copper and gold. The grade/tonnage model (Cox & Singer 1986) for porphyry copper gold deposits indicate that 90 per cent of these deposit contain at least 25 million tonnes of ore, 50 per cent contain at least 100 million tonnes of ore and 10 per cent contain at least 400 million tonnes. In 90 per cent of these deposits, the ore contains at least 0.35 per cent copper and 0.2 parts per million (ppm) gold, in 50 per cent of the deposits, ore contains at least 0.5 per cent copper and 0.38 ppm gold and in 10 per cent of the deposits the ore contains at least 0.72 per cent copper and 0.72 ppm gold. One of the largest deposits of this type is the Goonumbla group of deposits in NSW which contains 30 million tonnes of ore with 0.91 per cent copper and 0.63 ppm gold (Heithersay *et al.* 1990)

BM1: Volcanic associated massive sulphide deposits

(Model 28a of Cox and Singer, 1986)

Model description

Description of the model modified after Donald A. Singer, in Cox and Singer (1986).

Approximate synonym: Noranda type, volcanogenic massive sulfide, felsic to intermediate volcanic type.

Description: Copper, lead, zinc, silver, gold bearing massive sulfide deposits in marine volcanic rocks of intermediate to felsic composition.

General references: Ishihara (1974), Franklin *et al.* (1981), Hutchinson *et al.* (1982), Ohmoto and Skinner (1983), Large (1992), Allen and Barr (1990).

Geological environment

Rock types: Marine rhyolite, dacite, and subordinate basalt and associated sediments, principally organic-rich mudstone or shale. Pyritic, siliceous shale. Some basalt.

Textures: Flows, tuffs, pyroclastics, breccias, bedded sediment, and in some cases felsic domes.

Age range: Archean to Cainozoic.

Depositional environment: Hot springs related to marine volcanism, probably with anoxic marine conditions. Lead-rich deposits associated with abundant fine-grained volcanogenic sediments.

Tectonic setting(s): Island arc. Local extensional tectonic activity, faults, or fractures. Archaean greenstone belt.

Associated deposit types: Epithermal quartz-adularia veins in Japan are regionally associated but younger than Kuroko deposits. Volcanogenic Mn, Algoma Fe.

Deposit description

Mineralogy: Upper stratiform massive zone (black ore)--pyrite + sphalerite + chalcopyrite ± pyrrhotite ± galena ± barite ± tetrahedrite - tennantite ± bornite; lower stratiform massive zone (yellow ore)--pyrite + chalcopyrite ± sphalerite ± pyrrhotite ± magnetite; stringer

(stockwork) zone--pyrite + chalcopyrite (gold and silver). Gahnite in metamorphosed deposits. Gypsum/anhydrite present in some deposits.

Texture/structure: Massive (>60 per cent sulphides); in some cases, an underlying zone of ore stockwork, stringers or disseminated sulphides or sulfide-matrix breccia. Also slumped and redeposited ore with graded bedding.

Alteration: Adjacent to and blanketing massive sulfide in some deposits--zeolites, montmorillonite (and possibly chlorite); stringer (stockwork) zone--silica, chlorite, and sericite; below stringer--chlorite and albite. Cordierite and anthophyllite in footwall of metamorphosed deposits, graphitic schist in hanging wall.

Ore controls: Toward the more felsic top of volcanic or volcanic-sedimentary sequence. Near centre of felsic volcanism. May be locally brecciated or have felsic dome nearby. Pyritic siliceous rock (exhalite) may mark horizon at which deposits occur. Proximity to deposits may be indicated by sulfide clasts in volcanic breccias. Some deposits may be gravity-transported and deposited in paleo depressions in the seafloor. In Japan, best deposits have mudstone in hanging wall.

Weathering: Yellow, red, and brown gossans. Gahnite in stream sediments near some deposits.

Gossan may be high in Pb and typically Au is present. Adjacent to deposit-enriched in Mg and Zn, depleted in Na. Within deposits--Cu, Zn, Pb, Ba, As, Ag, Au, Se, Sn, Bi, Fe.

Examples

- Benambra, Australia (Allen and Barr 1990)
- Golden Grove, Australia (Frater 1983)
- Mount Lyell, Australia (Hills 1990)
- Rosebery, Australia (Lees *et al.* 1990)
- Thalanga, Australia (Gregory *et al.* 1990)
- Britannia, Canada (Payne *et al.* 1980)
- Buchans, Canada (Swanson *et al.* 1981)
- Kidd Creek, Canada (Walker *et al.* 1975)
- Furutobe, Japan (Hideo Kuroda 1983)

Known deposits and mineral occurrences in the Gippsland region

The region contains the two largest deposits of this type in Victoria, Wilga and Currawong. They are located within the Limestone Creek Graben which is one of the two remnants of the Cowombat Rift of Silurian age. Mineralisation in these grabens occurs at the base of the Gibsons Folly Formation, which consists of dacitic, andesitic and basaltic units with minor porphyritic rhyolite bodies, and is enclosed within turbiditic sediments. These rocks are inferred to have formed in relatively deep marine environment. The underlying Cowombat Siltstone is thought to belong to a shallow marine basin-slope facies. The Thorkidaan Volcanics, underlying the Cowombat Siltstone consists of marine volcanics of rhyolitic and dacitic compositions and are inferred to have been formed in a mixture of shallow water, deep water and sub-aerial conditions.

The James Flat prospect is located within the region but is hosted by the Lower Silurian Towanga Sandstone, which underlies the Thorkidaan Volcanics. In this prospect minor base metal mineralisation is recorded within quartz veins which infills cavities. The mineralisation

is thought to be of Upper Silurian age (Oppy *et al.* 1995). Mineral exploration in the area has recorded anomalous soil values of lead and zinc.

In the Wombat Creek Graben, north west of the Limestone Creek Graben, marine acid Mitta Mitta volcanics, of possible mid to late Silurian age, are overlain by the marine sediments of the Wombat Creek Group. Available data shows no volcanic rock component in the Wombat Creek Group but interbedded volcanic units may occur at depth and provide prospectivity for concealed VMS style deposits.

Exploration in the Wombat Creek Graben has been mainly at a reconnaissance or regional level and minor vein type copper, lead and minor zinc mineralisation has been recorded at several localities (e.g. Quart Pot, Silver Flat, Wombat Hole) in the Wombat Creek Graben (Oppy *et al.* 1995).

Devonian Dartella Group acid volcanics and sediments occupy the northern part of the Wombat Creek Graben and show few signs of exhalative mineralisation (Ramsay 1988, cited in Douglas & Ferguson 1988).

Devonian Snowy River Volcanics in the region also contain volcanogenic iron-manganese deposits with some elevated gold assays, and the upper part (Spring Creek Member) exhibits volcanic exhalative lead-zinc mineralisation and iron formations. At least some of the mineralisation in the overlying Devonian limestones and sediments (with minor volcanics) of the Buchan and Errinundra Groups is thought to be of volcanic exhalative origin (Ramsay 1988, cited in Douglas & Ferguson 1988).

Cambrian volcanic and volcanoclastic rocks in the region are also known to host several base metal occurrences. Exploration drilling in Cambrian rocks near Wrightly, located in the North-East Victoria RFA region but geologically associated with the north-west extension of the Cambrian greenstone belt, intersected banded pyrrhotite-rhodonite-chert mineralisation with volcanogenic characteristics. Recent exploration close to the region (within 15 kilometre buffer zone of the Gippsland region) has recognised volcanogenic gold-copper and gold-silver-barium mineralisation in altered calc-alkaline andesite lavas at Hill 800 near Jamieson (Maher *et al.* 1997, Fraser 1998).

Assessment criteria

1. Distribution of submarine volcanic, volcanoclastic rocks (Cambrian, Silurian and Devonian) and their metamorphosed equivalents.
2. Distribution of known base metal occurrences.

Assessment

Tract: BM1a/H/C

This tract delineates areas of Cambrian metabasalts, gabbro and sediments that have potential for volcanogenic base metal deposits. The Cambrian Mt Wellington greenstone belt in the region has several known base metal occurrences and prospects are currently being explored in the greenstone belt. Base metal and precious metal mineralisation of this type is known to occur in the North East Victoria RFA region.

Most Australian VMS base metals deposits are hosted by volcanic/sedimentary rock packages of calc-alkaline geochemical character. Cambrian andesites, andesitic agglomerates and tuffaceous sediments of this geochemical type occur near Jamieson, and extend southward towards Licola. The Licola andesites are geochemically similar to the Cambrian

Mount Read Volcanics of western Tasmania, which host major VMS base metal deposits (Crawford 1988).

The tract also includes marine volcanic and volcanoclastic rocks in the Limestone Creek Graben which localises two significant base metal deposits in the area.

Apart from the Gibsons Folly Formation which host the two significant deposits in the graben, undiscovered mineral deposits could also be hosted in rocks underlying the Gibsons Folly Formation (Cowombat Siltstone, Thorkidaan Volcanics and the Towonga Sandstone) in the Limestone Creek Graben and in the Reedy Creek Outlier. The Cowombat Siltstone is known to contain several massive sulphide base metal prospects in the Limestone Creek Graben.

It was mentioned earlier that the James Flat prospect is hosted in the Upper Silurian Towonga Sandstone. Lack of information does not allow assessing the role of the late Silurian Bindian deformation, which could have deformed, metamorphosed and remobilised the volcanic massive sulphide mineralisation.

The distribution of volcanic-hosted massive sulphide deposits in other areas, which are geologically similar to the one being assessed in the tract, shows that they are generally confined to one or maximum two stratigraphic levels. For instance in Noranda area (Canada) a large proportion of the deposits occur close to a single stratigraphical horizon (Lydon, 1988). Similarly, in Australia, five volcanic belts with known volcanic hosted massive sulphide deposits, only one mineralised horizon has been recognised. However, in the other two belts in Australia, the Mount Read Volcanics (Tasmania) and the Mount Windsor Volcanics (Queensland) there are at least two important stratigraphic levels of mineralisation (Large 1992).

The tract is thought to have a high potential for volcanogenic massive sulphide deposits, with a certainty level of C.

Tract: BM1b/M-H/B

The tract includes central and southern parts of the Buchan Rift where the Snowy River Volcanics are reported to be deposited in shallow marine environment.

In this area the volcanoclastics of the upper member of the Snowy River Volcanics, and the basal unit of the Buchan Caves Limestone frequently contain base metal mineralisation of volcanic exhalative origin. Mineral prospects of this type include the Shaw's Gully, Blue Bullocks Creek and Hackett Creek prospects and New Guinea lead occurrences. Detrital sphalerite and galena together with enriched manganese, barium and silver values with waterlain tuffs, pyritic shales and intraformational breccias point at the volcanic massive sulphide nature of mineralisation in these prospects.

The tract also consists of Silurian marine volcanic and sedimentary rocks deposited in the Wombat Creek Graben. Known mineralisation is confined to minor base metal occurrences in the Wombat Creek Group. In the Limestone Creek Graben, most significant VMS mineralisation is stratigraphically controlled by the Gibsons Folly Formation. It is possible the volcanic-sedimentary rocks of the Wombat Creek Group host a second horizon of mineralisation. It is also possible that these older rocks contain disseminated stockwork style mineralisation, often present below massive sulphide bodies in VMS deposits.

The tract also includes Devonian Sheevers Spur Rhyodacite. Devonian Dartella Volcanic Group which includes Sheevers Spur Rhyodacites in the northern part of the Graben show some signs of exhalative mineralisation (Ramsay 1988, cited in Douglas & Ferguson 1988)

but more importantly they may conceal underlying marine volcanic/sedimentary Silurian rocks with potential for VMS deposits.

Potential for volcanic hosted massive sulphide deposits in the tract is considered to be moderate to high with a certainty level of B.

Economic significance

Volcanic-hosted massive sulphide deposits are significant sources for copper, lead and zinc. Global grade/tonnage models for this type of deposit indicate that 90 per cent of these deposits have more than 0.12 million tonnes of mineralisation, 50 per cent have more than 1.5 million tonnes and 10 per cent have more than 18 million tonnes. Similarly, 90 per cent of these deposits have more than 0.45 per cent copper, 50 per cent have more than 1.3 per cent copper and 2.0 per cent zinc and 10 per cent have more than 3.5 per cent copper, 8.7 per cent zinc and 1.9 per cent lead.

Fifty per cent of this deposit type grade more than 0.16 grams per tonne gold and 13 grams per tonne silver, while 10 per cent have more than 2.3 grams per tonne gold and 100 grams per tonne silver.

Potential of associated deposit types: Gold associated with massive sulphide mineralisation

Volcanic hosted massive sulphide deposits are often associated with significant gold mineralisation. Many massive sulphide deposits in Tasmania such as Que River and Hellyer belong to this category. Volcanic-hosted massive sulphide deposits in the Captains Flat-Goulburn and the Hill End Synclinal zones also contain gold and silver mineralisation. Mineral occurrences in the Jamieson Window of Cambrian volcanic and volcanoclastic rocks have been reported to return gold values.

Assessment

Tract: Au5a/M-H/C

This tract coincides with the tract BM1a/H/C for volcanic associated massive sulphide deposits. The tract contains several occurrences of base metals with gold values.

The tract contains Silurian submarine volcanic rocks that host massive sulphide deposits of Wilga and Currawong near Benambra located in the Limestone Creek Graben. These deposits are known to have up to 1.3 grams per tonne gold (Allen and Barr 1990).

The likelihood of gold mineralisation associated with volcanic massive sulphide depends on the presence of volcanic massive sulphide deposits but not all massive sulphide deposits have significant gold mineralisation. Therefore the potential of this tract for gold mineralisation is assessed to be of a level lower than that of volcanic associated massive sulphide deposits. Hence the potential of the tract is assessed to be moderate to high with a certainty level of C.

Tract: Au5b/M/B

This tract coincides with the BM1b/M-H/B tract for volcanic associated massive sulphide deposits. The tract includes central and southern parts of the Buchan Rift where the volcanoclastics of the upper member of the Snowy River Volcanics, and the basal unit of the Buchan Caves Limestone frequently contain base metal mineralisation of volcanic exhalative origin. The tract also includes the Mitta Mitta Volcanics, the overlying Wombat Creek Group and the Dartella Volcanic Group in the Wombat Creek Graben.

For reasons similar to those outlined in the above tract, the potential of this tract is assessed to be moderate with a certainty level of B.

BM2: Irish-style carbonate hosted base metal deposits

Model description

Approximate synonyms: Carbonate hosted stratabound deposits.

Description: Stratabound and cross-cutting accumulations of sulphide and sulphate minerals within sequence of carbonate and clastic rock.

General reference: Hu and Large (1986)

Geological environment

Rock types: Mixed siliciclastic and carbonate rocks and locally evaporitic sediments in shallow marine, moderate to high oxidising shelf environment. The sequence succeeded by the deposition of shallow water shelf limestones and deeper water carbonates and argillite. Volcanic rocks of bimodal composition are locally present.

Textures: Host rocks are commonly micritic, oolitic, pelloidal or slightly sandy carbonate beds.

Age range: Commonly Palaeozoic. Deposits in Ireland are hosted in Lower Carboniferous rocks. The mineralisation is suggested to be formed in a short span of 7 million years during the latest Courcayan (approximately 353 million years) and the Early Arundian (approximately 345 million years). The latest Courcayan to Arundian corresponds to a period of tectonic activity including limited bimodal Volcanism in Central Ireland.

Depositional environment: Shallow marine shelf environment.

Tectonic setting: Overall tectonic environment setting is similar to that of both Selwyn Basin in Canada (which hosts the Sedex deposits) and the German Hercynian Basin (contains Meggen and Rammelsberg deposits). In all three areas large prisms of clastic sediments appear to have sharply abutted against well-developed carbonate shelves. Host rocks are formed during periods of limited volcanism, extensional tectonics followed by compression of one basin margin.

Associated deposit types: Bedded barite deposits.

Deposit description

Mineralogy: Sphalerite, galena, pyrite, marcasite, chalcopryrite, barite and carbonates. Minor to trace amounts of arsenopyrite, bornite, chalcocite, covellite, tennantite, semseyite, bournonite, freibergite, pyrrargyrite, boulangerite, cylindrite, frankeite, agryrodite, jordanite, gratonite, enargite, geocronite, native antimony, and fluorite and gypsum.

Texture/structure: Sulphides occur as inter-porosity fill, vein, irregular colloform bands replacing earlier bands of carbonates or sulphides and sulphates, coarse vug fillings, stylolites, and massive laminated bands. In crosscutting closed to the feeder mineralisation, sulphides form stockwork of veins, breccia fillings and massive replacement zones.

Alteration: Dolomitisation (often ferroan dolomite) and minor and local silicification. Alteration is lithologically controlled and argillaceous rocks are poorly dolomitised. Dolomitisation follows diagenetic infill cements by calcite. It is followed the precipitation of sulphides and carbonate material. Minor carbonate followed mineralisation.

Ore controls: Lithologically stratabound mineralisation is consistently restricted to non-argillaceous units and is generally best developed within micritic, oolitic, pelloidal or slightly sandy carbonate beds. Highest-grade mineralisation occurs commonly within porous and permeable oolitic, pelloidal or slightly sandy packstones and wackstones adjacent to less permeable argillaceous carbonates, fine-grained calstites or micrites. mineralisation adjacent to feeder structures cross cuts stratigraphy. The majority of mineral deposits are adjacent to structures (generally normal faults) that were active during mineralisation.

Geophysical signatures: IP anomalies used for exploration.

Geochemical signatures: Zinc and lead geochemical anomalies in soil and stream sediments.

Examples

- Navan, Ireland (Ashton *et al.* 1986)
- Silvermines, Ireland (Andrew 1986)
- Tynagh, Ireland (Banks 1986)

Known deposits and mineral prospects in the region

The Irish-Style base metal occurrences in the region are concentrated in two regions: in the Murrindal Syncline in the Buchan Rift and Bindi rifts. In the Murrindal syncline more than 40 base metal prospects showing features similar to the Irish-Style base metal deposits have been recorded. Important prospects of this type are: the Hume Lead and Pyramids Lead Mine, the Back Creek, Good Hope, Spring Creek and Neils Creek mines. Mineralisation in these prospects is located within basal dolomitic limestones. Recent work confirmed that these deposits display similarities with epigenetic zones of the Irish-style base metal deposits (VandenBerg *et al.* 1996). Geochemical similarities between the Irish and Buchan provinces have also been reported (VandenBerg *et al.* 1996). However, temperature of formation (160° to 210°C) is slightly lower than those for the Irish-style deposits, although they do indicate that a direct primary volcanic source is unlikely.

Similar rocks in the Boulder Flat Graben in the East Gippsland RFA region also contains a number of base metal prospects.

Assessment criteria

1. Distribution of rocks of the Buchan Groups formed in extensional related setting where limestones and clastics were deposited in shallow marine and shelf environment.
2. Geological setting characterised by active tectonism with possible concurrent volcanic activity.
3. Distribution of occurrences similar to the Irish-Style base metal deposits.

Assessment

Tract BM2/H/C

The tract is delineated based on the distribution of rocks belonging to the Buchan Group within the Buchan and Bindi rifts.

The Buchan Caves Limestone, which is the lowest member of the Buchan Group is thought to be formed in shallow marine environment (shallow sloping carbonate shelf) after the initiation of marine transgression in the southern part of the Buchan Rift. There is some evidence that volcanism on minor scale continued well after the onset of limestone deposition. As described above the area contains several prospects that have features similar to the Irish-style base metal deposits.

Based on the available information it is concluded that the tract has a high potential for the Irish-style base metal deposits with a certainty level of C.

Economic significance

Irish-Style base metal deposits are important sources of base metals as important as large volcanic-hosted massive sulphide deposits. The Navan deposit in Ireland has 90 million tonnes of ore with 2.3 per cent lead and 10 per cent zinc (Cox & Singer 1986). The other two deposits are comparatively smaller (Silvermines: 18 million tonnes with 2.8 per cent lead and 7.4 per cent zinc; and Tynagh: 12 million tonnes with 0.4 per cent copper, 4.9 per cent lead and 4.5 per cent zinc).

Sn1: Tin veins

(Model 15B of Cox and Singer, 1986)

Model description

Description of the model after B.L. Reed

Approximate synonym: Cornish type lodes.

Description: Simple to complex quartz-cassiterite $\pm$ wolframite and base-metal sulfide fissure fillings or replacement lodes in or near felsic plutonic rocks.

General reference: Solomon and Groves (1994), Hosking (1974), Taylor (1979).

Geological environment

Rock types: Close spatial relation to multiphase granitoids; specialised biotite and (or) muscovite leucogranite common; pelitic sediments generally present.

Textures: Common plutonic textures.

Age range: Paleozoic and Mesozoic most common; may be any age.

Depositional environment: Mesozonal to hypabyssal plutons; extrusive rocks generally absent; dykes and dyke swarms common.

Tectonic setting(s): Foldbelts and accreted margins with late orogenic to postorogenic granitoids, which may, in part, be anatectic; regional fractures common.

Associated deposit types: Sn greisen, Sn skarn, and replacement Sn deposits.

Deposit description

Mineralogy: Extremely varied; cassiterite $\pm$ wolframite, arsenopyrite, molybdenite, hematite, scheelite, beryl, galena, chalcopyrite, sphalerite, stannite, bismuthinite; although variations and overlaps are ubiquitous, many deposits show an inner zone of cassiterite $\pm$ wolframite fringed with Pb, Zn, Cu, and Ag sulfide minerals.

Texture/structure: Variable; brecciated bands, filled fissures, replacement, open cavities.

Alteration: Sericitisation (greisen development) $\pm$ tourmalisation common adjacent to veins and granite contacts; silicification, chloritisation, and hematisation. An idealised zonal relation might consist of quartz-tourmaline-topaz, quartz-tourmaline-sericite, quartz-sericite-chlorite, quartz-chlorite, and chlorite.

Ore controls: Economic concentrations of tin tend to occur within or above the apices of granitic cusps and ridges; localised controls include variations in vein structure, lithologic and structural changes, vein intersections, dykes, and cross-faults.

Weathering: Cassiterite in stream gravels, placer tin deposits.

Geochemical signature: Sn, As, W, B are good pathfinder elements; elements characteristic of specialised granites (F, Rb, Be, Nb, Cs, U, Mo, REE).

Examples

- Cornwall, Great Britain (Hosking 1969)
- Herberton, Australia (Blake 1972)

Known deposits and prospects in the Gippsland region

Within the Omeo zone, a phase of tin mineralisation (with local gold mineralisation) is hosted by quartz veins within Silurian S-type and Lower Devonian I-type granitoids (Oppy *et al.* 1995). Several tin fields are to the north of the Gippsland region; however, the only significant tin field within the region is the Surveyor's Creek field. At the Surveyor's Creek field, quartz veins containing tin mineralisation occur within the Boebuck Adamellite and the contact aureole of this intrusion. There are no production records of mining at the Surveyor's Creek field.

Alluvial tin has been worked along several creeks east of Bruthen (including Falls Creek). The catchment of these creeks includes the Upper Devonian Colquhoun Granite (Maps 1 and 2). This granite has patchy disseminated tin mineralisation (Oppy *et al.* 1995).

Alluvial tin and tin vein mineralisation occur at the Bunyip River and Toora prospects, and within granitoids on Wilsons Promontory (Douglas 1984) (Map 2).

Assessment criteria

1. S and I type granitoids
2. Fractionated (undergone extensive crystal fractionation)
3. Reduced – Ilmenite series
4. Presence of tin mineralisation.

Assessment

The map by Chappell *et al.* (1991) is used to classify granitoids of the Gippsland region into:

- I, S or A-types;
- fractionated/unfractionated; and
- felsic/mafic.

Tract Sn1a/M/B-C

Tract is based on the distribution of:

- granitoids, which are felsic, fractionated, non-magnetic, S-type or I-type, and have tin vein deposits. These are the Nuniong Granodiorite and Anglers Rest Granite (west of Benambra); and Silurian ‘fault rock’ granite to the northeast of Falls Creek (Figure 11). The Mount Singapore and Lilly Pilly Granites on Wilsons Promontory are associated with alluvial tin deposits;
- felsic dykes which are fractionated and have tin vein deposits. Aplitic dykes in an area to the northeast of Mount Pinnibar contain tin mineralisation (Figure 11). These are within the Surveyors Creek tinfield; and
- the tract includes a five kilometre buffer zone around the above granitoids and dykes.

This tract is assessed as having moderate potential. The certainty level is C for areas where the presence of granite is clearly defined. The certainty level is B for the five kilometre buffer around each granitoid and for areas where the granitoid is defined indirectly (e.g. presence of dykes).

Tract Sn1b/L-M/B-C

Tract is based on the distribution of felsic dykes and granitoids which are fractionated, non-magnetic, S or I-type, and for which there are no known occurrences of tin vein mineralisation. The Tynong Granite (northwest of Warragul) and Baw Baw Granodiorite (west of Walhalla) are included in this tract (Figure 11). The Tynong Granite has a single occurrence of tin mineralisation.

The tract includes a 5 km buffer zone around these granitoids and dykes.

This tract is assessed as having low to moderate potential. The certainty level is C for areas where the presence of granite is clearly defined. The certainty level is B for the five kilometre buffer around each granitoid and for areas where the granitoid is defined indirectly (e.g. presence of dykes).

Tract Sn1c/U/A

Tract is based on the distribution of non-magnetic granitoids, which are classified as ‘Un’ (unknown) or ‘no information’ (Note: If the ‘Un’ granitoids are magnetic then these are considered to have no potential for tin veins). Devonian dykes to the west of Falls Creek; and the Sarsfield Granite, immediately north of Bairnsdale are within this tract.

This tract is assessed as unknown potential with certainty level A.

Sn2: Tin greisen deposits (Model 15C of Cox and Singer, 1986)

Model description

Description of the model after BL Reed

Description: Disseminated cassiterite, and cassiterite-bearing veinlets, stockworks, lenses, pipes, and breccia in greisenised granite.

General reference: Reed (1982), Solomon and Groves (1994)

Geological environment

Rock types: Specialised biotite and (or) muscovite leucogranite (S-type); distinctive accessory minerals include topaz, fluorite, tourmaline, and beryl. Tin greisens are generally post-magmatic and associated with late fractionated melt.

Textures: Common plutonic rock textures, miarolitic cavities may be common; generally nonfoliated; equigranular textures may be more evolved; aplitic and porphyritic textures common.

Age range: May be any age; tin mineralisation temporally related to later stages of granitoid emplacement. Tasmanian deposits are associated with Devonian-Lower Carboniferous granitoids.

Depositional environment: Mesozonal plutonic to deep volcanic environment.

Tectonic setting(s): Foldbelts of thick sediments ± volcanic rocks deposited on stable cratonic shield; accreted margins; granitoids generally postdate major folding.

Associated deposit types: Quartz-cassiterite sulfide lodes, quartz-cassiterite ± molybdenite stockworks, and late complex tin-silver-sulfide veins.

Deposit description

Mineralogy: Cassiterite, molybdenite, arsenopyrite, beryl, wolframite, bismuthinite, Cu-Pb-Zn sulphide minerals and sulphostannates. Gangue mineralogy includes quartz, ± fluorite, calcite, tourmaline, muscovite and topaz.

Texture/structure: Exceedingly varied, the most common being disseminated cassiterite in greisens, and quartz veinlets and stockworks (in cupolas or in overlying wallrocks); less common are pipes, lenses, and tectonic breccia.

Alteration: Incipient greisen (granite): muscovite ± chlorite, tourmaline, and fluorite. Greisenised granite: quartz-muscovite-topaz-fluorite, ± tourmaline (original texture of granites retained). Greisen: quartz-muscovite-topaz ± fluorite ± tourmaline ± sulphides (typically no original texture preserved). Tourmaline can be ubiquitous as disseminations, concentrated or diffuse clots, or late fracture fillings. Greisen may form in any wallrock environment, typical assemblages developed in aluminosilicates.

Ore controls: Greisen lodes located in or near cupolas and ridges developed on the roof or along margins of granitoids; faults and fractures may be important ore controls.

Weathering: Granite may be ‘reddened’ close to greisen veins. Although massive greisen may not be economic as lodes, rich placer deposits form by weathering and erosion.

Geochemical signature: Cassiterite, topaz, and tourmaline in streams that drain exposed tin-rich greisens. Specialised granites may have high contents of SiO₂ (> 73 per cent) and K₂O (> 4 per cent), and are depleted in CaO, TiO₂, MgO, and total FeO. They are enriched in Sn, F, Rb, Li, Be, W, Mo, Pb, B, Nb, Cs, U, Th, Hf, Ta, and most REE, and impoverished in Ni, Cu, Cr, Co, V, Sc, Sr, La, and Ba.

Examples

- Lost River, United States (Dobson 1982, Sainsbury 1964)
- Anchor Mine, Australia (Solomon & Groves 1994)
- Erzgebirge, Czechoslovakia (Janecka & Stemprok 1967)

Known deposits and prospects in the Gippsland region

Within the Gippsland region, a phase of tin mineralisation is associated with NW-trending pegmatite-greisen dykes hosted by the Omeo Metamorphic Complex. This phase of tin mineralisation is interpreted to be Middle to Upper Silurian.

The Mt Wills-Wombat Creek tin field has both hard rock and alluvial workings. Tin-bearing dykes of this field are possibly the southern extensions of the Mitta Mitta Dyke Swarm.

The Mitta Mitta-Deans Creek tin field lies immediately to the north of the Gippsland region. Tin mineralisation occurs within greisenised aplite dykes of the Mitta Mitta Dyke Swarm.

Assessment criteria

1. Presence of tin-bearing aplite-pegmatite dyke swarms,
2. Distribution of fractionated, reduced (non-magnetic), S or I type, late orogenic to post orogenic granitoids (either outcropping or at shallow depth),
3. Distribution of greisenised granite,
4. Presence of greisen and alluvial tin.

Assessment

The map by Chappell *et al.* (1991) was used to classify granitoids of the Gippsland region into:

- I or S-types,
- fractionated/unfractionated,
- felsic/mafic.

Tract Sn2a/L-M/B

Tract is based on the distribution of:

- Felsic dykes, which are fractionated and have greisen tin deposits/prospects. This tract includes the southern extensions of the Mitta Mitta Dyke Swarm (north-east of Falls Creek). These mineralised dykes are part of the Mt Wills – Wombat Creek tinfield.

- Granitoids, which are, felsic, fractionated, non-magnetic, S-type or I-type, and have greisen tin deposits/prospects. Greisenised dykes northeast of Mount Pinnibar and Silurian ‘fault rock’ granitoid northeast of Falls Creek are included in this tract.

This tract is assessed as low to moderate potential with certainty level B.

Tract Sn2b/L/B

Tract is based on the distribution of granitoids, which are felsic, fractionated, non-magnetic, S-type or I-type, and for which there are no known occurrences of greisen mineralisation. This includes the Anglers Rest Granite (west of Benambra); the Baw Baw Granodiorite (west of Walhalla); the Tynong Granite (northeast of Warragul); and the Mt Singapore and Lilly Pilly Granites (Wilsons Promontory).

This tract is assessed as low potential with certainty level B.

Tract Sn2c/U/A

Tract is based on the distribution of non-magnetic granitoids, which are classified as ‘Un’ (unknown), or ‘no information’. These are the Sarsfield Granite (north of Bairnsdale); the Cobungra Granite (west of Omeo); and an unnamed granitoid southwest of Falls Creek.

This tract is assessed as unknown potential with certainty level A.

WMo: Tungsten-molybdenum veins

(Model 15A, Cox and Singer, 1986)

Model description

Description of the model after DP Cox and WC Bagby

Approximate synonym: Quartz-wolframite veins (Kelly & Rye 1979).

Description: Wolframite, molybdenite, and minor base-metal sulphides in quartz veins

General reference: Solomon and Groves (1994)

Geological environment

Rock types: Monzogranite to granite stocks intruding sandstone, shale, and metamorphic equivalents.

Textures: Phanerocrystalline igneous rocks, minor pegmatitic bodies, and porphyroaphanitic dykes.

Age range: Paleozoic to late Tertiary.

Depositional environment: Tensional fractures in epizonal granitic plutons and their wallrocks.

Tectonic setting(s): Belts of granitic plutons derived from remelting of continental crust. Country rocks are metamorphosed to greenschist facies.

Associated deposit types: Sn-W veins, pegmatites.

Deposit description

Mineralogy: Wolframite, molybdenite, bismuthinite, pyrite, pyrrhotite, arsenopyrite, bornite, chalcopyrite, scheelite, cassiterite, beryl, fluorite; also at Pasto Bueno, tetrahedrite-tennantite, sphalerite, galena, and minor enargite.

Texture/structure: Massive quartz veins with minor vughs, parallel walls, and local breccia.

Alteration: Deepest zones, pervasive albitisation; higher pervasive to vein-selvage pink K-feldspar replacement with minor disseminated REE minerals; upper zones, vein selvages of dark-grey muscovite or zinnwaldite (greisen). Chloritisation. Widespread tourmaline alteration at Isla de Pinos.

Ore controls: Swarms of parallel veins cutting granitic rocks or sedimentary rocks near igneous contacts.

Weathering: Wolframite persists in soils and stream sediments. Stolzite and tungstite may be weathering products.

Geochemical signature: W, Mo, Sn, Bi, As, Cu, Pb, Zn, Be, F.

Examples

- Pasto Bueno, Peru (Landis & Rye 1974)
- Xihuashan, China (Hsu 1943, Giuliani 1985, and personal visit)
- Isla de Pinos, Cuba (Page & McAllister, 1944)
- Hamme District, United States (Foose *et al.* 1980)
- Round Mountain, United States (Shawe *et al.* 1984)
- Chicote Grande, Bolivia

Known deposits and prospects in the Gippsland region

The Mount Murphy wolframite mine, located in the northern part of the Gippsland region, has been one of Victoria's largest tungsten producers. A total of 90.4 tonnes of tungsten concentrates have been produced from Mount Murphy during the period 1908 to 1920 (Oppy *et al.* 1995). Wolframite occurs in N-NE trending quartz veins hosted by the Omeo Metamorphic Complex, near the contact with the Buckwong Granodiorite.

Wolframite has been mined from the Fainting Range wolframite mine (Map 2, Figure 13). Mining ceased in about 1945. Mineralisation is within quartz veins controlled by faults within schist zones (Oppy *et al.* 1995).

Assessment criteria

1. Fractionated felsic/mafic granitoids with moderate levels of oxidation.
2. Presence of W-Mo mineralisation,

Assessment

Tract WMo1a/L-M/B

Tract is based on the distribution of:

- Granitoids, which are fractionated, moderately magnetic (moderately oxidised), S-type or I-type, and have W-Mo vein deposits. This tract includes the Tambo Crossing Tonolite

(north of Bruthen) — the Fainting Range wolframite deposit is in metamorphic rocks adjacent to this intrusion; the Anglers Rest Granite (north-west of Benambra) — several wolframite vein deposits are associated with this intrusion; the Baw Baw Granodiorite (west of Walhalla); and the Tynong Granite (north-west of Warragul).

- Silurian S-type granitoids which are felsic, unfractionated, moderately magnetic and have W-Mo vein deposits. This tract includes the Buckwong Granodiorite (near Mount Misery) and a number of Silurian granites (unnamed) located east of Mount Pinnibar, and northeast of Falls Creek. The Mount Murphy wolframite mine occurs in metamorphic rocks near the Buckwong Granodiorite.

The tract includes a five kilometre buffer zone around the above granitoids.

This tract is assessed as low to moderate potential with certainty level B.

Tract WMo1b/U/A

There are a several granitoids in the region, which are moderately magnetic, however there are insufficient data (Chappell *et al.* 1991) to determine if these intrusions are fractionated. There are no wolframite veins associated with these intrusions. The Nunniong granite and a large Silurian granitic complex are included because it is considered that there is a possibility that within these complexes (50 by 12 kilometres) there may be some fractionated intrusions. The potential of these granitoids cannot be assessed and hence their potential for W-Mo veins is 'Unknown'.

This tract is assessed as unknown potential with certainty level A.

W: Tungsten skarn deposits

(Model 14A of Cox and Singer, 1986)

Model description

Description of the model after DP Cox

Description: Scheelite in calc-silicate contact metasomatic rocks.

Approximate synonyms: Scheelite skarns of the tin-tungsten type (Solomon & Groves 1994).

General references: Kwak (1987), Einaudi and Burt (1982).

Geological environment

Rock types: Tonalite, granodiorite, quartz monzonite; limestone.

Textures: Granitic, granoblastic.

Age range: Mainly Mesozoic, but may be any age. Tasmanian deposits are associated with Devonian — Early Carboniferous intrusions

Depositional environment: Contacts and roof pendants of batholith and thermal aureoles of apical zones of stocks that intrude carbonate rocks. Adjacent to fault zones, which intersect the intrusion and the carbonate host, rocks.

Tectonic setting(s): Orogenic belts. Syn-late orogenic.

Associated deposit types: Sn-W skarns, Zn skarns.

Deposit description

Mineralogy: Scheelite ± molybdenite ± pyrrhotite ± sphalerite ± chalcopyrite ± bornite ± arsenopyrite ± pyrite ± magnetite ± traces of wolframite, fluorite, cassiterite, and native bismuth.

Alteration: Diopside-hedenbergite + grossular-andradite. Late stage spessartine + almandine. Outer barren wollastonite zone. Inner zone of massive quartz may be present.

Ore controls: Carbonate rocks in thermal aureoles of intrusions. Fault which intersect the intrusion and the carbonate beds have acted as conduits to the mineralising fluids, particularly faults which pre-date the intrusion.

Geochemical signature: W, Mo, Zn, Cu, Sn, Bi, Be, As.

Examples

- King Island, Australia, Tasmania (Solomon & Groves 1994)
- Pine Creek, US, California (Newberry 1982)
- MacTung, Canada, British Columbia (Dick & Hodgson 1982)
- Strawberry, US, California (Nokleberg 1981)

Known deposits and mineral prospects in the Gippsland region

The Nowa Nowa magnetite bodies are within skarns.

Late stage intrusions of the Thorkidaan Volcanics intrude the Towonga Sandstone and Cowombat Siltstone, both of which contain large limestone megacrysts. Skarns have formed in these limestones.

Skarn wollastonite deposits occur in the Seldom Seen Formation (Wulgulmerang wollastonite) and in the Wombat Creek Group (Morass Creek wollastonite).

The Fainting Range deposit contains wolframite and scheelite in quartz veins. From the available data it is not possible to conclude that the mineralisation is skarn type. Therefore it is not included in the skarn tract.

Assessment criteria

1. I-type granitoids which have undergone fractional crystallisation and are moderately oxidised,
2. Granitoids associated with W skarns are more oxidised (magnetite series) than those associated with tin deposits (ilmenite series),
3. Presence of reactive host rocks, which were intruded by the granitoid, bodies. Carbonate-rich sediments can react with hydrothermal fluids to produce skarn deposits.
4. Skarn deposits are located at the outer surface of the granite and in haloes around the granite. Locations within a few hundred metres of the contact have the highest potential.

5. Skarn deposits are concentrated in the upper portions of the granitic body. Consequently granitic bodies where the roof of the granite is at shallow depth (cupola) have a higher potential than deeply weathered granitic bodies.

Tract W1a/M/C

This tract contains the following lithological units:

- Pinnuk Sandstone which hosts the Nowa Nowa magnetite skarn deposit,
- Seldom Seen Formation which hosts the Wulgulmerang wollastonite occurrence,
- Cowombat Siltstone which hosts the Morass Creek wollastonite occurrence.

This tract is assessed as having a moderate potential with certainty level C.

Tract W1b/L-M/B

This tract contains the following:

- A five kilometre wide zone adjacent to the margins of Palaeozoic granitoids, which are potential source, rocks for tungsten mineralisation, i.e.
 - Granitoids which are felsic, fractionated, moderately magnetic (moderately oxidised) S-type or I-type, and have W-Mo vein deposits,
 - Silurian S-type granitoids, which are felsic, unfractionated, moderately magnetic and have W-Mo vein deposits (Mount Murphy wolfram mine).
- Palaeozoic limestones and dolomites which were intruded by these granitoids, i.e. Boola Formation, Buchan Caves Limestone, Cowombat Siltstone, Murrindal Limestone, Norton Gully Sandstone, Seldom Seen Formation, Toravale Marlstone, Towonga Sandstone, Wurutwun Formation, and Devonian hornfels.

The intersection of these calcareous rocks with the five kilometre buffer zone around the granitoids defines the tract for tungsten skarn mineralisation. This tract is assessed as having low to moderate potential with certainty level B.

Tract W1c/U/A

This tract is the intersection of calcareous rocks with the five kilometre buffer zone around those granitoids, which have an unknown potential for W-Mo mineralisation. These granites are the same as those for the tungsten-molybdenum tract WMo1b/U/A.

This tract is assessed as unknown potential with certainty level A.

NiCu: Synorogenic-synvolcanic nickel-copper

(Model 7A of Cox and Singer, 1986)

Model description

Description of the model modified after Norman J Page.

Approximate synonyms: Ni-Cu in mafic rocks; Stratabound sulphide-bearing Ni-Cu; gabbroid associated Ni-Cu.

Description: Massive lenses, matrix and disseminated sulphide in small to medium sized gabbroic intrusions in fold belts and greenstone belts.

General references: Hoatson *et al.* (1992), Ross and Travis (1981), Marston *et al.* (1981).

Geological environment

Rock types: Host rocks include norite, gabbro-norite, pyroxenite, peridotite, troctolite, and anorthosite, hornblendite, forming layered or composite igneous complexes.

Textures: Phase and cryptic layering sometimes present, rocks usually cumulates.

Age range: Archaean to Tertiary, predominantly Archaean and Proterozoic; Cambrian in Tasmania, Devonian in Victoria.

Depositional environment: Intruded synvolcanically or tectonically during orogenic development of a metamorphosed terrane containing volcanic and sedimentary rocks.

Tectonic setting(s): Mobile belts; metamorphic belts, greenstone belts.

Associated deposit types: Stratiform mafic-ultramafic Ni-Cu (Stillwater); Stratiform mafic-ultramafic PGE (Merensky Reef, Bushveld Complex); placer areaomite —PGM.

Deposit description

Mineralogy: Pyrrhotite + pentlandite + chalcopyrite ± pyrite ± Ti-magnetite ± Cr-magnetite ± graphite; with possible by-product Co and PGE's.

Texture/structure: Predominantly disseminated sulphides in stratabound layers up to three metres thick; commonly deformed and metamorphosed so primary textures and mineralogy may be modified.

Alteration: Alteration (serpentinisation, etc.) can be marked in this deposit type.

Ore control: Sulphides may be near the basal contacts of the intrusion but are generally associated more with gabbroic dominated rather than basal ultramafic cumulates.

Weathering: May be recessive if altered; may form nickeliferous laterites over the ultramafic portions in low latitudes.

Geochemical signature: Ni, Cu, Co, PGE, Cr.

Geophysical signature: Strong magnetic signature where not extensively serpentinised.

Examples

- Sally Malay, Western Australia (Thornett 1981)
- Radio Hill, Mount Sholl, Western Australia (Hoatson *et al.* 1992)
- Rana, Norway (Boyd & Mathiesen 1979)
- Moxie pluton, US, Massachusetts (Thompson & Naldrett 1984)
- Cuni deposits (Five mile), Australia, Tasmania (Blissett 1962, Horvath 1957)

Known deposits and mineral occurrences in the Gippsland region

Most known occurrences of nickel-copper in the region are associated with the Woods Point Dyke swarm, either hosted by the dykes or the surrounding Devonian country rocks. The most well-known of this is the Thomson River copper mine (Coopers Creek copper mine) where mineralisation occurs in ‘bulges’ or thickenings in the width of the dyke generally in the vicinity of a series of drag folds in what appears to be an en echelon arrangement. Disseminated and massive copper nickel sulphides occur within diorite/hornblendite dyke.

A number of gold mines in the Central Highlands RFA region, just to the west of the Gippsland region, are hosted by the Woods Point swarm have produced copper and platinoids as by-products. Principal amongst these are Hunt’s, the New Loch Fine, the Shamrock and Morning Star mines.

Assessment criteria

1. Presence of mafic rocks or altered mafic rocks in the area (Thomson River is hosted by the more mafic members of the dyke swarm e.g. hornblendite).
2. Presence of stratabound nickel copper sulphide mineralisation in gabbro/dolerite sills associated with ultramafic complexes.

Assessment

Tract: NiCu/M-H/B

The tract includes the Woods Point Dyke Swarm and the surrounding Devonian (meta) sedimentary country rocks (Walhalla Group, Montys Hutt Formation and Norton Gully Sandstone). These rocks have the potential to host small copper nickel deposits of the Thomson River type where thickenings or bulges in the dykes occur. The dykes contain mineralisation characteristic of this model type (synorogenic Ni-Cu) and hence the entire known outcrop area of the Woods Point Dyke Swarm is assessed as having moderate to high potential and it has a certainty level of B.

Economic significance

The gabbroid associated stratabound nickel copper sulphide deposit type has been of minor commercial importance in Tasmania in the past. However, this deposit type is of world significance overseas as an important source of nickel and as a source of strategically important PGE’s.

U: Sandstone uranium

(Model 30C of Cox and Singer, 1986)

Model description

Description of the model after Areaistine E Turner-Peterson and Carroll A Hodges

Approximate synonyms: Tabular U ore, roll front U.

Description: Microcrystalline uranium oxides and silicates deposited during diagenesis in localised reduced environments within fine- to medium-grained sandstone beds; some uranium oxides also deposited during redistribution by ground water at interface between oxidised and reduced ground.

General references: Turner-Peterson and Fishman (1986), Granger and Warren (1969).

Geological environment

Rock types: Host rocks are feldspathic or tuffaceous sandstone. Pyroclastic material is felsic in composition. Mudstone or shale commonly above and/or below sandstones hosting diagenetic ores.

Textures: Permeable--medium to coarse grained; highly permeable at time of mineralisation, subsequently restricted by cementation and alteration.

Age range: Most deposits are Devonian and younger. Secondary roll-front deposits mainly Tertiary.

Depositional environment: Continental-basin margins, fluvial channels, braided stream deposits, stable coastal plain. Contemporaneous felsic volcanism or eroding felsic plutons are sources of U. In tabular ore, source rocks for ore-related fluids are commonly in overlying or underlying mud-flat facies sediments.

Tectonic setting(s): Stable platform or foreland-interior basin, shelf margin; adjacent major uplifts provide favourable topographic conditions.

Associated deposit types: Sediment-hosted V may be intimately associated with U. Sediment-hosted Cu may be in similar host rocks and may contain U.

Deposit description

Mineralogy: Uraninite, coffinite, and pyrite in organic-rich horizons. Chlorite common.

Texture/structure: Stratabound deposits. Tabular U--intimately admixed with pore-filling humin in tabular lenses suspended within reduced sandstone. Replacement of wood and other carbonaceous material. Roll front U--in crescent-shaped lens that cuts across bedding, at interface between oxidised and reduced ground.

Alteration: Tabular--Humic acid mineralising fluids leach iron from detrital magnetite-ilmenite leaving relict TiO₂ minerals in diagenetic ores. Roll front--Oxidised iron minerals in rock up-dip, reduced iron minerals in rock down-dip from redox interface.

Ore controls: Permeability. Tabular--Humin or carbonaceous material the main concentrator of U. Roll front--S species, 'sour' gas, FeS₂. Bedding sequences with low dips; felsic plutons or felsic tuffaceous sediments adjacent to or above host rock are favourable source for U. Regional redox interface marks locus of ore deposition.

Weathering: Oxidation of primary uraninite or coffinite to a variety of minerals, notably yellow carnotite as bloom in V-rich ores.

Geochemical and geophysical signature: U, V, Mo, Se, locally Cu, Ag. Anomalous radioactivity from daughter products of U. Low magnetic susceptibility in and near tabular ores.

Examples

- Honeymoon, Beverley South Australia (Battey *et al.* 1987)
- Colorado Plateau (Fischer 1974)

- Grants, US, New Mexico (Turner-Peterson and Fishman 1986)
- Texas Gulf Coast (Reynolds & Goldhaber 1983)

Known deposits and mineral occurrences in the Gippsland region

There are no known occurrences of sediment-hosted uranium in the region, although anomalous concentrations of uranium are known in reduced sediments within the red bed sequences in the Mansfield and the Mount Typo Basins to the northwest of the Gippsland region. Drilling in one hole in the Mount Typo Basin located uranium, vanadium mineralisation along with copper and silver (average grade of representative samples were 4.65 per cent copper, 38 parts per million (ppm) silver, 539 ppm uranium and 290 ppm vanadium). In the Gippsland region, anomalous radiometric values for uranium have been located in the redbeds in the Macalister, Avon and Mitchell River Basins. Redbed sequences are also known to occur in the Mount Tambo Group which may also contain uranium deposits.

Apart from redbed sequences, there is also potential for sandstone type uranium deposits in the reduced sandstones of the Lower Cretaceous Strzelecki Group. Uranium in such deposits may have been derived from uranium mineralisation in the granitoids in the Ballarat-Bendigo Zone and in the Omeo Zone.

Assessment criteria

Criteria for uranium deposits in redbed sequences:

1. Presence of interbedded redbeds and reduced sediments
2. Presence of uranium occurrences and anomalies.
3. Presence of uranium-bearing granitoids and volcanic source rocks

Criteria for uranium deposits in reduced sandstones of the Strzelecki Group:

1. Presence of sandstones deposited in a reducing environment and containing carbonaceous plant material and/or interbedded coal layers.
2. Presence of uranium-bearing granitoids, which are a possible source for uranium that could be dissolved by circulating groundwater and precipitated at redox, interfaces within the sandstone.

Assessment

Tract: U1a/L-M/B-C

The tract for uranium deposits in the red beds is defined by the extent of the Macalister, Avon and Mitchell River Basins, and the Mount Tambo Group of sediments, all of which contain redbed sequences. Anomalous concentrations of uranium, sometimes associated with the copper occurrences have been recorded in them. Airborne uranium channel radiometric anomalies are generally low for the redbed sequences but can be locally high in the vicinity of some of the copper occurrences.

Secondary uranium mineralisation has been recorded within granitoids in the Ballarat-Bendigo zone and in the Omeo Zone (Bowen 1988c). Within the Melbourne Zone, the granitoids and volcanics have low uranium contents. These rocks may provide a source of uranium for deposition as sandstone type deposits.

On the available information the potential for small sandstone uranium deposits is low to moderate at the interfaces of reducing and oxidising conditions in the redbeds in all of the basins with a certainty level of C.

The tract also includes the distribution of Lower Cretaceous Strzelecki Group sediments of the Gippsland Basin. The Lower Cretaceous sandstones of the Strzelecki Group were deposited in a reducing environment and unconformably overlie Palaeozoic basement sediments and granitic rocks. The sediments contain carbonaceous plant material and interbedded coal layers (Douglas 1988) and are suitable host rocks for sandstone uranium deposits. Palaeochannels eroded into the basement would localise the inflow of oxidised groundwaters containing dissolved uranium. Uranium precipitation occurs at redox interfaces (roll-fronts) within the sandstone beds.

Devonian granitoids and volcanics within the Melbourne Zone contain low levels of uranium. These provide a possible source for the formation of sandstone uranium deposits. However, the potential for this type of deposit is reduced because of the low background levels of uranium in the granites.

On the available information the potential for sandstone uranium deposits is low to moderate with a certainty level of B to C. Lower levels of certainty (B) apply to areas occupied by Lower Cretaceous Strzelecki Group sediments.

Economic significance

In United States and Kazakhstan, sandstone type uranium deposits represent important sources for uranium.

Cu1: Sediment-hosted copper deposits (Redbed subtype)

Model description

Description of the model modified after Dennis P Cox and after Kirkham (1996)

Approximate synonym: Sandstone Cu, Zambian Copper, Zechstein Copper, sedimentary copper; includes Cu-shale (Lindsay 1982); ‘Stratiform’ copper. Kirkham (1996) subdivides sediment hosted copper deposits into the ‘Kuperschiefer’ and the ‘Redbed’ subtypes.

Description: Deposit broadly conformable, stratabound; ‘stratiform’ or mostly parallel to enclosing sediments; disseminated copper sulphides in reduced beds of a red-bed sequence.

General references: Sawkins (1984), Tourtelot and Vine (1976), Gustafson and Williams (1981), Kirkham (1996).

Geological environment

Rock types: Host Rocks include sandstones, siltstones, shales, carbonaceous pyritic shales, dolomites and/or limestones. Associated rocks include basal conglomerate, red shale and siltstone (red-bed sequence); gypsum/anhydrite, stromatolites and algal laminated dolomite, mafic intrusives and/or mafic basement. Red-bed sequence containing green or grey shale, siltstone, and sandstone. Thinly laminated carbonate and evaporite beds. Local channel conglomerates. Some deposits in thinly laminated silty dolomite.

Textures: Algal mat structures, mudcracks, crossbedding and scour-and-fill structures.

Age range: Palaeoproterozoic to Neoproterozoic (especially in Australia). Also Phanerozoic (mainly Permian but as young as Miocene overseas).

Depositional environment: Fault bounded graben/trough, or basin margin or epicontinental shallow-marine basin near paleo-equator; shallow water lagoonal or lacustrine sediments, partly evaporitic on the flanks of basement highs; sabkha terrains. High evaporation rate. Basal sediments highly permeable.

Tectonic setting(s): Extensional setting, i.e. intra-cratonic rift; intracontinental rift or aulacogen; failed arm of triple junction of plate spreading. (Passive) continental margin. Major growth faults.

Associated deposit types: Basalt copper, Unconformity-type uranium; Sandstone uranium, Tsumeb copper and Kipushi type Cu-Pb-Zn.

Deposit description

Mineralogy: Fine to medium grained spatially zoned assemblages comprising chalcopyrite, bornite, digenite, djurleite, chalcocite, $\pm$ native silver, minor pyrite with associated carrollite, vaesite, minor sphalerite, tennantite, trace galena, and Ge, U & Ni minerals.

Texture/structure: Disseminated, intergranular; rarely sub-massive; occasionally in sedimentary breccia. Often rimming and partially replacing coarse dolomite and quartz, and cementing carbonate and quartz grains in sandstone. Generally replacing earlier formed pyrite, which may be framboidal or colloform.

Alteration: Little visible alteration. May be evidence of liesegang-ring structures indicating redox solution front mixing in red hematitic fine clastics; some dolomitisation, silicification, chloritisation, & K-feldspar enrichment in some cases. Green, white, or grey (reduced) colour in some red beds where present. Regionally metamorphosed red beds may have purple colour.

Ore controls: Adjacent to, and unconformably overlying, older basement highs; mineralisation at top of the first cycle of a fining-upward conglomerate to shale red-bed sequence. Evidence of pre-existing pyrite or trapped bi-sulphides in pore spaces at the first reduced horizon above the base of the rift sequence, and/or the presence of gypsum or other evaporites associated with stromatolitic hypersaline carbonate rocks (dolomite or ferroan dolomite) at top of first cycle. Presence of copper-rich mafic basement rocks, rift tholeiites or mafic intrusives within the rift sequence. Presence of potential ore fluid aquifers e.g. Basal permeable sandstones and/or major faults; occurrence of reduced environment such as algal mats; abundant biogenic sulfur and/or pyritic sediments. Presence of evaporites or evaporite pseudomorphs is indicative of potential sulphur source to form metal sulphides. Evidence of cross-faults, embayments, closed basins/sub-basins during sedimentation plus evidence for growth faults in the vicinity of active basement highs where rapid changes in sedimentary units/facies occur is considered favourable. Such facies changes are considered to provide a contrast in permeability and oxidation states thus forming physical and chemical traps.

Weathering: Surface exposures may be completely leached. Low sulphur systems such as these do not tend to produce very substantial or massive gossans, with weathering of sulphides leaving perhaps only remnant limonite with cuprite or malachite/azurite or chrysocolla.

Geochemical signature: Cu, Co, Ag, U, Zn, and Ge. Gold and PGE's not common.

Geophysical signature: IP can be effective. Weak radioactivity occurs in some deposits.

In typical redbed subtype copper deposits, the redbed sequence consist of successive cycles of fluvial sediments starting with coarser reduced and permeable sandstones at the base of the cycle and grading to fine grained oxic, less permeable shales and siltstones near the top of the cycle. The best concentrations of copper and silver are near the base in the more permeable sandstones at reducing/oxidising interfaces.

Typical redbed copper deposits such as Dorchester and Naciminto are much smaller than the Kupferschiefer subtypes. The much larger deposits at Dzhezkazgan and Revett Formation included in this subtype by Kirkham (1996) involve large scale invasion of reducing solutions into the redbeds resulting in extensive oxidising/reducing interfaces where copper is deposited.

Examples

Kupferschiefer subtype:

- Mount Gunson, Australia
- Mammoth (Gunpowder), Australia
- Mount Oxide, Australia
- Kupferschiefer, Germany (Wedepohl 1971)
- White Pine, United States (Brown 1971)
- Western Montana (Belt), United States (Harrison 1972, 1982)
- Kamoto, Zaire (Bartholome *et al.* 1976)

Redbed subtype:

- Dorchester, New Brunswick
- Naciminto, New Mexico (Woodward *et al.* 1974)
- Dzhezkazgan district, Kazakhstan
- Revett Formation, Montana
- Corocoro, Charcarilla, Bolivia

Known deposits and mineral occurrences in the Gippsland region

Low grade copper mineralisation has been located by past exploration in the Upper Devonian Snowy Plains Formation in the Macalister, Avon and Mitchell River Basins. These basins are about 100, 60, and 30 km respectively northwest of Bairnsdale.

In the Avon and Mitchell River Basins the mineralisation is in reduced zones of the oxidised red bed Iguana Creek Mudstone member. Elevated uranium and thorium radiometric values also correspond to this geological unit (Maher *et al.* 1996).

At Freestone Creek in the Avon River Basin, mine workings occur over a mineralised zone of chalcopyrite veins within a 0.3 metre thick grey siltstone over a length of 50 metres. Chalcopyrite and malachite occur over a 3 metre interval within a similar unit in the Iguana Creek in the Mitchell River Basin. The copper grades are generally less than 0.1 per cent with a maximum of 0.59 per cent. There is no record of copper production. Red bed type copper mineralisation has also been noted in the Macalister basin by VandenBerg (1977).

Red bed sequences are also known to occur in the Mount Tambo Group in a graben structure south of Benambra. According to Maher *et al.* (1996), copper-uranium deposits may be present in these red beds, which have not been tested by exploration.

The copper occurrences are similar to red bed copper-uranium-vanadium deposits elsewhere in the world.

Assessment criteria

1. Presence of interbedded redbeds and reduced sediments
2. Presence of copper occurrences and copper anomalies
3. Presence of fault and fold structures in the basement and the basin sediments

Assessment

Tracts: Cu1a/M/B-C

The tracts for sediment hosted copper and sandstone uranium are defined by the extent of the late Devonian redbed sequences in the Avon and Mitchell River Basins. Interfaces of reducing and oxidising environments in the redbeds together with structural traps in the basin and faults in the underlying basement rocks provide favourable settings for deposition of copper, silver and less frequently uranium from metal-bearing solutions. On the available evidence from exploration data, the redbeds in these basins are assigned a moderate potential for small deposits of copper with a certainty level of C.

The tract also includes the Macalister Basin and the Mount Tambo Group. Some copper occurrences have been recorded in the Macalister Basin but the extent of copper occurrences in the Mount Tambo Group is not known due to lack of exploration data. The Macalister Basin is also underexplored for these types of deposits. These red bed sequences are considered to have a moderate potential with a certainty level of B due to lack of exploration data.

Economic significance

Redbed copper deposits of major significance are in Kazakhstan and there are important deposits in Revett Formation in Montana. Elsewhere known sediment hosted copper deposits of the redbed type are relatively unimportant as compared to the giant sediment hosted copper deposits of the Kupferschiefer subtype in Europe and in Zambia and Zaire. Some of the redbed type copper deposits have high silver content (e.g. Revett Formation) which makes them economically more attractive.

Elsewhere in the world, sediment hosted copper deposits represent major sources for copper.

Brown coal deposits

Model description

Description of Coal-bearing sedimentary sequences

Approximate synonyms:

Description: Coal measures.

General references: Harrington (1989), Traves *et al.* (1975), Doyle *et al.* (1986).

Geological environment

Rock types: Coal measures interbedded with various terrestrial and marine sedimentary sequences.

Age range: Carboniferous to Tertiary

Depositional environment: Peat swamps behind coastal barrier systems or within structural depressions further inland; swamps and peat bogs associated with and marginal to alluvial fans and deltaic plains; fluvial flood plains; lacustrine; lagoonal. Depositional environment must be free from frequent incursions of clastic sediments or oxygenated waters, thus environments are generally low energy, anoxic and occur in fresh – brackish waters.

Tectonic setting: Small rifts and valleys, marginal and intracontinental sedimentary basins. Coal deposition is generally closely related to marine transgression and/or regression. Deposits are dominantly terrestrial, with marine influence common.

Associated deposit types: Oil Shale?

Deposit description

Mineralogy/composition: Coal composition varies depending on depositional environment and extent of coalification.

Brown coal—Moisture content 50–70 per cent, dry weight: 60–75 per cent Carbon.

Bituminous coal—Moisture content 5–10 per cent, dry weight: 80–90 per cent Carbon.

Anthracite—Moisture content 2–5 per cent, dry weight: 90–95 per cent Carbon.

(After Doyle *et al.* 1986)

Dominant components of coals are macerals and ash. Macerals are the organically derived components of coal. The major components of coal ash are silicate and sulfide minerals.

Texture/structure: Generally laterally continuous seams. Can have various textures relating to sedimentary processes such as fluvial channels or marine incursion. Differing environments of deposition and subsequent decay and decomposition of plant material can also result in differing lithotypes and banding within seams. Jointing in deformed coals?

Ore controls: Limits of sedimentary basins; deformation subsequent to coalification; faults in basement; local structure and differential compaction of coal seams may influence location of depocentres.

Examples

- Gippsland Basin, Australia, Victoria (Barton *et al.* 1992)

Known deposits and mineral prospects in the Gippsland region

Within the southern section of the Gippsland region lies the bulk of the onshore Gippsland Basin containing massive brown coal resources of Tertiary age. Extensive sequences of sediments, including coal precursors, accumulated during slow, steady subsidence over most of the Tertiary. The onshore Gippsland Basin has an area of approximately 8 000 square kilometres and is one of the world's major coal bearing basins. The Gippsland Basin first

developed as a rift basin during the Early Cretaceous. Rifting, related to the separation of Antarctica from Australia, recommenced during the Late Cretaceous, initiating a long period of relatively stable and continuous subsidence that led to the deposition of the large sedimentary sequences including thick coal seams.

The Latrobe Valley Depression, a sub-unit of the onshore Gippsland Basin, lies within the Gippsland RFA area. The Tertiary sediments occupy an elongated, asymmetric, east-pitching syncline bounded to the south by the Gippsland Hills and to the north by the Yallourn monocline. Over long periods of steady and slow subsidence, the coal forming swamps were protected in the east from marine conditions by a narrow but continuous barrier sand complex known as the Balook Formation. The Latrobe Valley depression contains most of the Gippsland region's coal resources including the remarkably thick seams of the Morwell and Yallourn formations. All the major coal seams in the Latrobe Valley occur as oval-shaped bodies of coal elongated along the centre of the depression, covering an area varying between 550 and 700 square kilometres, and each seam area includes one or more depocentres where continuous coal exceeds 80 metres thickness. The Yallourn Formation is the top most and hence youngest coal bearing formation in the Latrobe Valley and is dated at Middle Miocene age.

In a similar manner to the Morwell Formation, which it conformably overlies, the Yallourn Formation grades laterally eastwards into barrier sands (Balook Formation) of the Seaspray Group. The formation is comprised mainly of the Yallourn seam but the deeper synclines may include up to 200 metres of clay above the coal seam. Where the underlying Morwell 1A seam is fully developed, the two seams are separated by an interim burden known as the Yallourn clay which can be up to five metres in thickness. The Yallourn and Morwell seams are massive, well-defined deposits of coal (with a maximum thickness of 105 metres and 165 metres respectively – Gloe *et al.* 1988) supporting large mining operations.

At Loy Yang, near Traralgon, where the Yallourn and Morwell Formations are underlain by the Traralgon Formation and interseam sediments are either thin or missing, it is possible to find up to 300 metres of coal with only minor clay breaks (Durie 1991). Proven economic deposits of coal at Loy Yang amount to over 5 000 million tonnes (Gloe *et al.* 1988). The Stradbroke coalfield to the southeast consists of a block of high quality brown coal made up of the Traralgon 1 and Traralgon 2 seams, the latter reaching a maximum thickness of 136 metres (Durie 1991). All of the open cuts so far developed in the Latrobe Valley are excavating coal from the Yallourn and Morwell Formations.

The Gelliondale-Alberton Depression, located in the southern most onshore part of the Gippsland Basin, contains the Gelliondale and Alberton coalfields and lies within the Gippsland region. The structural pattern of the Gelliondale-Alberton Depression appears to represent that of the Latrobe Valley Depression. However, in this area the direction of elongation is parallel to the barrier sands (Balook Formation), whereas in the Latrobe Valley the dominant direction of elongation is normal to the barrier sequence. The Alberton coalfield contains two main seams with a combined thickness of about 55 metres and total resources are estimated at 4 900 million tonnes of which 2 000 million tonnes are classified as economic. The main Gelliondale coal seam is 50 metres or more thick and, of 5 200 million tonnes of demonstrated coal resources in the Gelliondale Exploration Licence, 1 050 million tonnes are considered to be economically recoverable (Durie 1991).

The Moe Swamp Basin, another sub-basin of the Gippsland Basin, overlaps the boundary of the Gippsland region. Limits of the Moe Swamp Basin are the Yallourn Monocline in the east, the Darnum Monocline in the west and the Yarragon Monocline in the south. Tertiary cover wedging out against a southward dipping Palaeozoic basement represents the northern edge of the basin. The host of the major coal seams in the basin is the Yarragon Formation,

which contains interbedded sands, clays and coal. Two major brown coal seams of 5–15 metres and 25–36 metres thickness respectively, as well as several very thin seams, are present within the Yarragon Formation near the township of Moe. The thickness of coal sequences of economic interest is largely controlled by the upthrown edge of the Moe Monocline in the east and a similar structure near Yarragon in the west of the basin. Reserves in the Yarragon Formation near the township of Yarragon (200 million tonnes — Stanley 1986) lie just within the RFA zone. Reserves of brown coal in the Yarragon Formation for the Moe coalfield (104 million tonnes — Gloe 1979) extend into the buffer area. The Yarragon Formation seams are correlated with the Yallourn and Morwell seams of the Latrobe Valley respectively.

The Wonthaggi black coal coalfield lies about 12 kilometres west of the southwestern boundary of the Gippsland but there is insufficient data to assess potential for black coal.

Assessment criteria

1. Presence of the coal bearing formations.
2. Extents of 2:1 overburden ratio, seams thicker than 3 metres and seams shallower than 300 metres.
3. Evidence for coal at depth, either boreholes or evidence from gravity surveys.
4. Proximity of known coal deposits.

Assessment

Tract Bcoal/H/D

The tract has been delineated within the onshore Gippsland Basin. The tract consists of large areas of Late Tertiary and Quaternary sediments that overlie extensive coal seams. There is evidence from drilling that brown coal is widespread throughout the Tertiary sediments of the Gippsland Basin. The tract is based on geological parameters derived from drill hole and other data regarding the quality, depth and overburden ratio of brown coal seams. For regions where resources have a minimum seam thickness of three metres, an overburden: coal ratio of 2:1 or better, and a maximum depth of 300 metres, a mineral potential of high and a certainty level of D have been assigned.

Tract Bcoal/M-H/C

The tract includes the remainder of the onshore Gippsland Basin Tertiary sediments. There is evidence from drilling that brown coal is widespread throughout the Tertiary sediments of the Gippsland Basin. Where at least one of the three criteria (a minimum seam thickness of three metres, an overburden:coal ratio of 2:1 or better and a maximum depth of 300 metres) is not met, a mineral potential of moderate to high and a certainty level of C have been assigned.

Economic significance

The onshore Gippsland Basin is one of the world's major coal bearing basins. Total brown coal reserves for the Gippsland Basin have been estimated at 96 300 million tonnes, while total resources have been calculated at over 172 874 million tonnes (Gloe & Holdgate 1991).

Within the Gippsland region, most significantly is the Latrobe Valley coalfield with 86 200 million tonnes of resources meeting the three geological criteria of; an overburden:coal ratio of 2:1 or less, a minimum seam thickness of three metres, and a

maximum coal depth of 300 metres. Also meeting these three geological criteria and within the Gippsland region are the Stradbroke coalfield, the Gelliondale-Alberton coalfield, the Yarragon coalfield, and much of the Moe coalfield. The Koo-Wee-Rup coalfield extends from the west and marginally continues into the Gippsland region. The Wonthaggi black coal coalfield lies within the southeastern most part of the Gippsland region.

Production for 1923–1998 from the Morwell, Yallourn, Yallourn North, Yallourn North Extension and Loy Yang mines totals 1 333 million tonnes (Barton *et al.* 1992, BRS estimate 1997, NRE 1996–1998). At this rate of use the reserves identified so far in the Gippsland Basin would last several thousand years. Brown coal in Victoria is mainly used for electricity generation but briquettes are also produced for industrial and domestic use.

DIMST: Dimension stone (granite, basalt, limestone, marble, sandstone, and slate)

Model description

Description of the model after Hora (1992)

Approximate synonyms: Freestone, building stone.

Description: Geological materials suitable for dimension stone uses.

General references: Hora (1992), Sharples (1990).

Geological environment

Rock types: Intrusive and extrusive of mafic, felsic and ultramafic, and alkaline composition. Limestones, sandstone, shales, and phyllites.

Age range: Precambrian to Tertiary.

Depositional environment and tectonic setting: Synorogenic and postorogenic plutonic intrusions. Post orogenic volcanics. Sedimentary marine and continental rocks. Metasedimentary and Meta-igneous rocks that have undergone contact and/or regional metamorphism.

Deposit description

Mineralogy: Typical of granites, basalts, limestone, marbles, sandstone, shales, phyllite etc.

Texture/structure: Massive, bedded, porphyritic, hornfelsic spotted.

Alteration: Effect of weathering: Structural deterioration, decrease in strength and durability. In limestones and marbles weathering results in variety of karst features. Marbles with silicate components (tremolite, phlogopite, and garnet) might significantly deteriorate in durability and strength. Effects of metamorphism: granites could change into gneiss, which may also be quarried as dimension stone. Limestone and marble undergo recrystallisation resulting in more massive beds, sometimes with enhanced colours and texture features and more suitable for polish.

Ore controls: Frequency of joints. Common types of granite can afford some 20 per cent waste, only rare and attractive varieties can have waste up to 80 per cent of quarried rock. For

marbles and limestones and sandstones, thick bedding (greater than one metre), absence of fractures and joints, absence of inhomogeneities like chert, and other type of silica staining components like sulphides, absence of intrusive sills and dikes, absence of solution cavities in carbonate rocks.

Weathering: Leads to structural deterioration and decrease in strength and durability.

Geochemical signatures: Nil

Geophysical signatures: Resistivity has been used to identify low fracture densities in granites and karst features in limestones and marbles.

Known deposits and mineral occurrences in the Gippsland region

The Gippsland region has a number of potential sources of dimension stone of various types as listed below.

Locality	Type
Colquhoun (just east of the region)	Granite
Mount Taylor	Granite
The Brothers	Syenite
Bindi	Marble
Buchan (just east of the region)	Marble
Limestone Creek	Marble

The Colquhoun Granite is a fine-grained pink-red granite that has been used for monumental purposes. Tertiary sediments cover large areas of granite subcrop but it has a reasonable potential as a dimension stone resource depending on the amount of overburden and land use status. The Mount Taylor Granite, which is partly pink and coarsely porphyritic, is also suitable for dimension stone use (Maher *et al.* 1996).

Pale brown syenite outcropping on the southern slopes of The Brothers is a potential source for dimension stone (Maher *et al.* 1996).

Devonian crystalline limestones, commonly termed marbles, from Buchan have been used in many buildings constructed from last century to the late 1940s and the region has high potential for more grey marbles for dimension stone. Silurian marble at Bindi features an attractive fabric but local jointing may affect its marketability (Maher *et al.* 1996).

Silurian marbles in the Limestone Creek, Stony Creek and Claire Creek areas display a wide range of attractive colours. Marble lenses occupy areas exceeding 12 hectares and contain large quantities of massive marble, and there are small disused marble quarries at Limestone Creek and Stony Creek. This limestone has good potential for use as monumental and dimension stone, although its extraction is limited by the bulk of its outcrop occurring within the Cobberas-Tingaringy National Park (King & Weston 1997).

Widely scattered lenses of Devonian crystalline limestone are also present within the Norton Gully Sandstone and the Walhalla Group in the western part of the region. Some of these lenses have been quarried for ornamental stone, notably those at Toongabbie and Howes Creek (Griffiths quarry).

Devonian-Carboniferous sandstones of the Snowy Plains Formation in the MacAlister, Avon and Mitchell River Basins constitute potential sources for dimension stone. The sandstone at Briagolong has been used for local buildings and shows no significant deterioration even

after 105 years of exposure (King & Weston 1997). An Extractive Industry Work Authority was granted for quarrying micaceous lithic sandstones in the Valencia Creek-Avon River area. The Devonian-Carboniferous basins are largely unexplored for dimension stone and the range of colour and the durable nature of these sandstones suggest good resource potential.

Assessment criteria

1. Distribution of suitable granitoids, and alkaline igneous rocks.
2. Distribution of sedimentary and metasedimentary rocks such as marble, limestone, sandstone, shale and phyllite.
3. Presence of known quarries and occurrences.

Assessment

Tract Dimst1a/H/C

The tract includes the Devonian granitoids of the Colquhoun Granite and the Triassic trachytic and syenitic rocks of the Mount Leinster Igneous Complex. The tract also includes the Devonian Buchan Caves Limestone and the Murrindal Limestone. These rocks host known quarries and occurrences of dimension stone.

On the available information these rocks in the tract are considered to have a high potential for dimension stone with a certainty level of C.

Tract Dimst1b/M-H/B

The tract is defined by the presence of Late Devonian-Carboniferous Snowy Plains Formation with sandstones in the MacAlister, Avon River and the Mitchell River Basins. The tract includes carbonate sequences with potential for dimension stone in the Silurian Cowombat Siltstone in the Limestone Creek Graben and the Wombat Creek Group.

The geological characteristics of these rocks and the presence of known occurrences and quarries indicates that these rocks have a moderate to high potential for dimension stone with a certainty level of B.

Tract: Dimst1c/M/C

This tract is defined by Devonian Tynong Granite on the southwestern edge of the region. The Tynong Granite has been used previously as a dimension stone for the Shrine of Remembrance and to a lesser extent in some other buildings. This granite is well located on transport routes to Melbourne. The presence of some pyrite and jointing in the granite detracts from its potential as a dimension stone but the extensive area underlain by the granite is largely untested.

On the available information the Tynong Granite in this tract has a moderate potential for dimension stone with a certainty level of C.

Tract: Dimst1d/L/B-C

Lenses of crystalline limestone occur within the Norton Gully Sandstone and the Wurutwun? Formation in the western part of the region. Limestones from these lenses have been extracted for ornamental purposes at Toongabbie and Griffiths quarries. The limestones of the Walhalla Group in the Tyers River – Coopers Creek area are also considered to have potential for dimension stone (King & Weston 1997).

The possible sources for dimension stone in this part of the region is limited to widely scattered lenses of crystalline limestone within the two formations and for this reason the potential over the whole of the tract is considered to be low. The certainty level is B and C.

Lst: Limestone

Model description

Description of the model after D Hora (1992).

Approximate synonyms: Limerock, cement rock, calcium carbonate.

Description: Limestone deposits of economic importance were partly or wholly biologically derived from seawater and accumulated in a relatively shallow marine environment. Environment of deposition determines the size, shape and purity of the carbonate rock. Limestone deposits are frequently of large areal extent and may be of considerable thickness (several hundred metres).

General references: Carr and Rooney (1983), Harben and Bates (1990)

Geological environment

Rock types: Limestone

Age range: Late Proterozoic to Holocene.

Depositional environment: Belts of shallow sea water sediments.

Tectonic setting(s): Continental shelf and subsiding marginal marine basins.

Associated deposit types: Deposits of dolomitic limestones and dolomites.

Deposit description

Mineralogy: Limestone is a sedimentary rock consisting of 50 per cent or more of calcite (CaCO_3), and dolomite ($\text{CaMg}(\text{CO}_3)_2$). There is a complete gradation from impure limestone to high calcium limestone (>95% CaCO_3). In dolomites, the mineral dolomite is the major carbonate, which usually forms by replacement of calcite. Common impurities in carbonate rocks include clay, quartz sand, chert, and organic matter.

Texture/structure: Massive, bedded.

Alteration: Groundwater dissolution results in karst cavities frequently filled with clay.

Ore controls: Highly sought white limestones for mineral fillers are usually a product of the contact or regional metamorphic process. Maximum limitations of overburden: Extremely varied depending on the end use. Limestones are known to be mined underground even for uses like cement production.

Weathering: solutions weathering results in a variety of karst landforms in most climatic areas, but intensifies with warmer climate.

Geochemical signature:

Geophysical signature: Resistivity has been used to identify karst features in covered terrain.

Examples

- Silurian Marulan and Wombeyan Limestones of NSW
- Tertiary Eucla Basin limestones, e.g. Nullarbor Limestone of WA and SA; Tertiary Batesford Limestone and Gambier Limestone of Victoria and SA.

Known deposits and mineral occurrences in the Gippsland region

There are three main areas of known limestone occurrences and resources in Gippsland region. They are:

- the limestones of Silurian age in the Limestone Creek and Wombat Creek Grabens and limestones of Lower Devonian age, in the north east of the region. Just outside the eastern boundary of the region is the Buchan Caves Limestone in the Buchan Rift, which constitutes a major limestone resource. A major quarry is present at Rocky Camp, about 12 kilometres east of the region. This limestone also occurs at Bindi inside the region. Silurian age limestones at Morass Creek and Wombat Creek are also potential sources for limestone extraction but some of this limestone is in national parks;
- other Devonian limestones occur as lenses in the Walhalla Group, and in the Tabberabbera Formation in the southwestern part of the region. Limestone is extracted from the Boola Quarry, north of Tyers and also occurs at Coopers Creek, Toongabbie and Licola; and
- tertiary age Gippsland Limestone crops out in the southern part of the region and are up to 500 metres thick onshore, but its surface exposures are confined to stream courses. It has been quarried at Merriman Creek for cement manufacture and at Darriman and several other localities for agricultural lime production.

Assessment criteria

1. Presence of Silurian-Devonian marine sedimentary rocks.
2. Presence of Tertiary limestone.
3. Presence of known occurrences of limestone and marble.

Assessment

Tract Lst1a/H/C

The tract is defined by the Silurian-Devonian sedimentary rocks, which may contain limestones. The tract includes the Cowombat Siltstone, Wombat Creek Group, Buchan Caves Limestone and the Murrindal Limestone in the northeast of the region.

The tract includes extensive outcrops of limestone and is considered to have a high potential for limestone/dolomitic limestone deposits with a certainty level of C.

Tract Lst1b/M-H/B

The tract is delineated by the distribution of the Tertiary age Gippsland Limestone as exposed in drainage courses and includes a 100 metre buffer on stream courses downstream from the occurrences. Elsewhere Tertiary sand and clay deposits extensively overlie the unit.

The tract is considered to have moderate to high potential for limestone deposits with a certainty level of B.

Tract Lst1c/M/B

The tract is defined by other Devonian limestones in the southwestern part of the region and includes the Walhalla Group sediments, which host the Tyers River, Coopers Creek, and Toongabbie quarries.

The tract is considered to have a moderate potential for limestone/dolomitic limestone deposits with a certainty level of B.

Economic significance

Limestone/dolomitic limestone, like many other industrial minerals, have a low value per unit of volume but it is essential that they are accessible in large quantities close to urban areas for use in construction. Thus competing land uses are a constant pressure on the availability of these resources. Other uses are in agriculture, roads and fillers for paper and plastic. Production in Victoria has fluctuated between 2.5 and 3 million tonnes since 1969–70 but dropped below 2 million tonnes in the early 1990s.

Limestone/dolomitic limestone deposits usually need to be either outcropping or near surface to be economic to extract. Distance from markets is also an important factor in the viability of a limestone/dolomitic limestone deposit as transport makes up a substantial proportion of product costs.

Model Silsnd: Silica sand

Model description

Approximate synonyms: Fluvial and dune silica sand deposits.

Description: Unconsolidated fluvial, beach and aeolian dune sand; commonly of Tertiary and Quaternary age.

General references: McHaffie and Buckley (1995), Cooper and Sawers (1990).

Geological environment

Rock types: Poor to well sorted fine to coarse grained beach, dune and fluvial quartz sand deposits.

Age range: Commonly Tertiary to Recent but can be of any age. Original source rocks may be of any age.

Depositional environment: Stable mature coastal region for well-sorted deposition of fluvial sand deposits and/or winnowing and sorting of dune and beach sand deposits. However poorly sorted quartzose sediments deposited in high-energy environments are also used for manufacture of silica sand but such sediments require additional sorting and processing.

Tectonic setting(s): Crustal stability during deposition and preservation of deposits.

Associated deposit types: Heavy mineral dune and beach sand deposits, placer type deposits.

Deposit description

Mineralogy: Silica quartz sand of high purity, preferably absence of iron staining, low heavy mineral and clay content.

Texture/structure: May be confined to fluvial deposits, dune or beach sands.

Alteration:

Ore controls: Usually stable mature coastal environment for effective sorting of fluvial material and/or efficient sorting and winnowing of beach and dune sands. However, poorly sorted quartzose sediments deposited in high-energy environments are also used for manufacture of silica sand.

Weathering: Deep leaching may remove heavy mineral fraction and iron staining.

Geochemical signature: None.

Geophysical signature: Relatively high resistivity, low radiometric response.

Known deposits and mineral prospects in Gippsland

A major silica sand mining operation is situated about seven kilometres west of the southwestern boundary of the region. The sources for the silica sand at the site are Quaternary dune sand and the underlying fluvial sand deposits of the Haunted Hills Formation. Both of these types of sand deposits are widespread in the southern part of the region, and the latter is of particular economic significance.

Assessment criteria

1. Extent of Tertiary fluvial deposits of the Haunted Hills Formation and Quaternary dunefields.
2. Known sand occurrences and silica sand deposits.

Assessment

Tract: Silsnd1a/H/C

The tract defines Quaternary dune sands and the Tertiary Haunted Hills Formation sands being mined for silica sand at Lang Lang and also includes Tertiary deposits north of Yarram within the region. The tract is considered to have a high potential for silica sand with a certainty level of C.

Tract: Silsnd1b/M/B

This tract includes the Haunted Hills Formation in the southern part of the region that contains fluvial sediments where silica sand may be present. The tract is assessed to have a moderate potential for silica sand deposits with a certainty level of B.

Tract: Silsnd1b/L/B

The tract includes Quaternary coastal and inland dune sand deposits and swamp deposits. There is some possibility that silica sand deposits suitable for industrial use may be present. The tract is assessed to have a low potential for silica sand deposits with a certainty level of B.

Economic significance

Australia accounts for about 2 per cent of the world's production of silica. Victoria produces about 240 000 tonnes per annum. Most of the silica sand production in Victoria is used for glassmaking. The rest is used for fibreglass manufacture, abrasives, foundry sands, ceramics, silex balls, paint additives and ornamental stone. Industries using silica are well established in Victoria (McHaffie & Buckley 1995). The largest producer of silica sands in Australia is from dune sands at Cape Flattery, located on Cape York Peninsula, Queensland. The production from Cape Flattery is exported to Japan (70 per cent), Korea, Taiwan, and the Philippines. In general however silica extraction is dictated by cost of transport and distance from markets.

KAO: Kaolin

Model description

Description of the model after D Hora (1992).

Synonyms: Primary kaolin, secondary kaolin.

General references: Harben and Bates (1990), Hora (1992), Lefond (1985).

Geological environment

Rock types: Kaolinised feldspathic rocks, like granites to diorites with their volcanic equivalents. Secondary alluvial kaolinitic clays.

Age range: The age range for kaolinisation is Upper Cretaceous to Eocene, but the parent rock ages may be much older.

Tectonic setting: Down-faulted sedimentary basins but may also include uplifted plateaus etc.

Depositional environment: Interior basins and flat alluvial plains with basement composed of feldspathic rocks. Alteration of feldspathic rocks by hydrothermal and/or residual weathering. Also feldspathic volcanic rocks may be the host for kaolin deposits, particularly where faults may provide the channels for circulating ground waters. Secondary alluvial clays eroded from primary deposits laid down in Tertiary and Quaternary river channels and lakes.

Associated deposit types: Fire clay, bentonite, coal, ceramic and cement 'shales'.

Deposit description

Mineralogy: Kaolin, quartz, feldspar, with minor biotite and hornblende.

Alteration mineralogy: Not applicable.

Ore controls: Unconformity and fractured basement rocks.

Examples

- Weipa, Queensland, Australia
- Pittong, Victoria, Australia
- Lang Bay, Sumas Mountain, British Columbia, Canada

Known deposits

Primary (or residual) kaolin forms by in-place weathering of feldspar-rich rocks such as granite, gneiss, arkose or some sediments. Deep weathering under hot, humid conditions (McHaffie 1992 in McHaffie & Buckley 1995) in Victoria during the late Cretaceous and early Tertiary periods generated extensive, thick kaolinitic surficial zones. (Residual kaolin resulting from the weathering of a Devonian granite is mined at Pittong, outside the region, by English China Clays International Ltd.)

The primary kaolinitic zones were largely eroded away later in the Tertiary and Quaternary and provided the source material for secondary (or alluvial) kaolinitic clay deposits. Slightly ligneous secondary kaolinitic clay deposits are known below the mid-Tertiary age Morwell No 1 brown coal seam in the Morwell open cut mine and at the brown coal open cut at Yallourn. At Morwell the clay reaches up to 10 metres in thickness and has been worked intermittently and used in whiteware manufacture. Secondary kaolin has been worked in the past at Heyfield and exploration at Boisdale has delineated up to 10 metres of secondary kaolin (in the fluvial Haunted Hills Formation) under an overburden of about six metres.

Assessment criteria

1. Presence of Tertiary deep weathering (primary deposits) profiles.
2. Presence of feldspar rich rocks.
3. Tertiary and Quaternary unconsolidated sediments (secondary deposits).
4. Presence of brown coal basins.
5. Presence of known occurrences.

Assessment

Tract Kao1a/H/C-D

The tract is delineated by the extent of the coal seams within the mining leases in the vicinity of the Morwell and Yallourn open pit mining operations where secondary kaolin deposits are known to underlie the coal seams. The tract also includes a two kilometre buffer around the two known occurrences of kaolin at Heyfield and Boisdale.

The tract is considered to have a high potential for kaolin deposits with a certainty level of D in the vicinity of the Morwell and Yallourn operations and a level of C at Boisdale and Heyfield.

Tract Kao1b/M/B

The tract is delineated by the extent of the brown coal seams within the Gippsland Basin that have an overburden of 2:1 or less. The potential kaolin deposits underlying the coal seams within this tract is assessed as moderate with a certainty level of B.

Tract Kao1c/L/C

This tract is defined by the extent of the fluvial sediments of the Haunted Hills Formation that are known to contain secondary kaolin at Boisdale and other deposits of kaolin may be present elsewhere. The tract is considered to have a low mineral potential for kaolin deposits with a certainty level of C.

Economic significance

Kaolin, like many other industrial minerals, has a low value per unit of volume and it is essential that it is accessible in large quantities close to urban areas for industrial applications and construction. Thus competing land uses are a constant pressure on the availability of these resources.

Victorian production of kaolin has averaged 145 000 tonnes per year (McHaffie & Buckley 1995).

Bxt: Lateritic type bauxite deposits

(Model 38B by Cox and Singer, 1986)

Model description

Description after Sam H Patterson

Approximate synonym: Aluminium ore (Patterson 1967).

Description: Weathered residual material in subsoil formed on any rock containing aluminium.

General reference: Patterson (1984).

Geological environment

Rock types: Weathered rock formed on aluminous silicate rocks.

Textures: Pisolitic, massive, nodular, earthy.

Age range: Mainly Cainozoic, one Cretaceous deposit known.

Depositional environment: Surficial weathering on well-drained plateaus in regions with warm to hot and wet climates. Locally deposits in poorly drained areas low in Fe due to its removal by organic complexing.

Tectonic setting(s): Typically occurs on plateaus in tectonically stable areas.

Associated deposit types: Overlain by thin 'A' horizon soil, underlain by saprolite (parent rock in intermediate stages of weathering).

Deposit description

Mineralogy: Mainly gibbsite and mixture of gibbsite and boehmite; gangue minerals hematite, goethite, anatase, locally quartz

Texture/structure: Pisolitic, massive, earthy, nodular.

Alteration: Aluminous rocks are altered by weathering to bauxite.

Ore controls: Thoroughly weathered rock, commonly erosional boundaries of old plateau remnants.

Weathering: Intensive weathering required to form bauxite. Bauxite continues to form in present weathering environment in most deposits.

Geochemical signature: Al., Ga.

Geophysical signature:

Examples

- Weipa, Queensland, Australia (Schaap 1990)
- Gippsland region, Victoria (McHaffie and Buckley 1995)

Known occurrences and deposits of bauxite in the Gippsland region

A cluster of 40 deposits lies about 20 kilometres south-west of Morwell and includes the only known deposits with economic significance in Victoria. They consist of small residuals formed by deep weathering of the Lower Tertiary Older Volcanics basalt/tuff near Boolarra and Mirboo North. Estimated initial resources of the two largest deposits, Napier 1 and Watkins, were about 200 000 tonnes of bauxite each and the other deposits contained less than 50 000 tonnes each. A substantial proportion of these resources has now been worked out and no current resource estimates are available (Nott 1988 in McHaffie & Buckley 1995).

Undiscovered deposits of bauxite may be present where bauxite weathering profiles have been developed over Lower Tertiary Older Volcanics.

Assessment criteria

1. Distribution of Older Volcanics basalts.
2. Distribution of Tertiary weathering profiles.
3. Distribution of Tertiary grabens.
4. Distribution of known bauxite occurrences and deposits.

Assessment

Tract: Bxt/M/C

The tract is delineated based on the distribution of Tertiary volcanics that include tholeiitic and minor alkaline basalts. Deep weathering of these can produce bauxite deposits. The tract also includes known bauxite occurrences and deposits. Based on the available information the potential of bauxite deposits is assessed to be moderate with a certainty level of C.

Economic significance

In other parts of Australia bauxite deposits at Weipa, Gove and the Darling Ranges are major resources of aluminium. The deposits in the Gippsland region are only a fraction of this size.

Total recorded bauxite production for Victoria since 1926 is about 200 000 tonnes and in 1991–92 was about 5 000 tonnes (McHaffie & Buckley 1995). Bauxite mining for production of aluminium salts began in Victoria in 1919 near Thorpdale, and Geelong Cement and Asko Chemicals mined bauxite until 1992 from the Paynes and Watkins deposits just north of Mirboo North for use mainly as an additive in cement manufacture. Resources at the Watkins and Paynes deposits are sufficient for many years at past production rates, and Geelong Cement has found significant new resources near Paynes. At Watkins there is a substantial

resource of high alumina clay beneath the bauxite (Nott 1988, cited in McHaffie & Buckley 1995).

CONMAT: Construction materials

Model description

Approximate synonyms: The term extractive resources is used as a synonym for construction materials. Various terms are used for construction aggregates depending on size and specific use. Such terms include hard rock aggregate, coarse aggregate, crushed and broken stone, rip rap, decorative aggregate, prepared road base, fine aggregate, construction sand, sand and gravel, river stone, shingle.

Descriptive terms for clays used in construction include clay/shale, structural clay, brick clay, low cost clay, stoneware clay, pipe clay, terra cotta clay.

Known deposits in the Gippsland region

Basalt for road making, building and concreting has been quarried from Older Volcanics at Yallourn North, Jeeralang North, Ruby, Dumbalk North and Leongatha South. Sandstone for road building is quarried from a number of localities.

Granite aggregate is extracted from the Sarsfield Granite, north of Bairnsdale, and granitic rocks are extracted from the Tynong North area, just west of the region (McHaffie & Buckley 1995). Rhyodacite aggregate has been quarried from the Snowy River Volcanics near Nowa Nowa, just east of the region. All these rock types may extend into the region.

Limestone and sandstone used for agriculture and aggregate is extracted from the Seaspray and Sale Groups between Bairnsdale and Orbost in the southeast and just east of the region. Murrindal Limestone used for agriculture, flux, lime and road base is extracted at Rocky Camp, just east of the region.

Sand and gravel pits operated by the former Department of Conservation and Natural Resources are an important local source of road surfacing material (Maher *et al.* 1996). The Haunted Hills Formation is the principal source of sand and gravel in the southwest of the region and it is used in roads, housing construction, concreting and pipe manufacture (Douglas 1984). Major potential construction sand resource areas are at Trafalgar and overlying brown coal basins in the Latrobe Valley in the southwest corner of the region (McHaffie & Buckley 1995).

Erosion of the Cretaceous/Tertiary clays formed alluvial clay deposits later in the Tertiary and Quaternary periods and extensive deposits are associated with brown coal in the Latrobe Valley region (McHaffie & Buckley 1995).

Soft, weathered siltstone from the Boola Formation and Tertiary alluvial clays have been used make bricks at Traralgon. Clays from the Tertiary Childers Formation and from weathered Mesozoic sediments have also been used for structural clay products.

Assessment criteria

1. Presence of soft or weathered rock.
2. Presence of Tertiary and Quaternary soil and sediments.

3. Presence of granite, acid to basic volcanics and hornfels.
4. Proximity to construction material markets/end use points and viable transport routes.

Assessment

Higher value construction materials

The potential for economic deposits of higher value construction materials in the Gippsland region exists where suitable rock types, gravels sands and clays occur within viable transport distances of population centres. The viable transport radius around a centre increases with population size because of the economies of scale of supplying a larger market and better road networks around larger centres. Deposits near good transport routes such as the Princes Highway and other major roads, with access to distant population centres may also be viable. Major population centres around which there would be a higher demand for construction materials include Warragul, Traralgon, Sale, Bairnsdale and Lakes Entrance.

Lower value construction materials

Most of the rock types in the Gippsland region have potential for lower value construction materials in their fresh or weathered state; and soil, sand and gravel are widespread across the region. Suitable materials are mainly used for secondary road building and extraction of material usually occurs in close proximity to these roads. The materials include: (1) rippable sandstone, shale, schist, weathered granite and other rock, (2) sand and gravel, (3) soil and clay.

Economic significance

Construction materials, like many other industrial minerals, have a low value per unit of volume and transport costs contribute significantly to their delivered cost. Thus it is essential that they are accessible in large quantities close to urban areas for use in construction, paving, water reticulation and many other uses which are the an integral part of modern living.

Fundamental infrastructure, such as road and railway networks, depend on widespread availability of crushed rock, sand, clay and other materials for their construction and maintenance. Similarly, major and minor aircraft runways and ports are all built with a significant input of construction materials.

Construction sand is commonly used in concrete, mortar, plaster and asphalt mixes. Special uses include glass and fibre glass manufacture, metal casting moulds, sand blasting and filtering media. Clay and clay shale are used in large quantities to make bricks, pipes and roofing tiles.

Appendix C Mineral resources metadata sheets

VIC: Geological maps database

Organisation	Department of Natural Resources and Environment Minerals and Petroleum Victoria
Abstract	The geological maps database is a digital version of the 1:250 000 scale geological maps of Victoria.
Contents	Citation Information Dataset Description Spatial Domain Contact Information Dataset Currency and Status Dataset Storage and Format Dataset Quality Metadata Contact Information
Citation information	<i>Data set title:</i> Victorian 1:250 000 Geological maps database <i>Data set short title:</i> Vic GEOL. <i>Jurisdiction:</i> Victoria <i>Custodian:</i> Department of Natural Resources and Environment, Minerals and Petroleum Victoria <i>Publication date:</i> Dec 1995 <i>Acknowledgments:</i> <i>References:</i>
Dataset description	<i>Abstract:</i> The Geological Maps Database is a digital version of the 1:250 000 scale geological maps of Victoria that were compiled during the 1970s and 1980s. Some areas have been updated from more recent 1:100 000 scale mapping. <i>Search words:</i> Geosciences, Geology <i>Location description:</i> Gippsland, Victoria
Spatial domain	<i>North bounding coordinate:</i> -36.515 <i>East bounding coordinate:</i> 148.219 <i>South bounding coordinate:</i> -39.138 <i>West bounding coordinate:</i> 145.667 <i>Bounding polygon:</i> <i>Attribute list:</i> See attached listing

Contact information	Contact organisation: Department of Natural Resources and Environment, Minerals and Petroleum Victoria Contact position: Manager, Geological Mapping Contact person: Peter O'Shea Contact address: PO Box 500, East Melbourne, Vic 3002 City: Melbourne State: Victoria Contact phone: 03 9412 5093 Contact fax: 03 9412 5155 Contact email: peter.oshea@nre.vic.gov.au
Dataset currency and status	Beginning date: 1970 Ending date: 1992 Progress: In progress Maintenance and update frequency: Irregular
Dataset storage and format	Stored data format: Digital — polygon, Hardcopy — Maps Output data format: Digital — polygon, Hardcopy — Maps Native data format: Available in Genemap, MapInfo or ArcView formats Access constraints:
Dataset quality	Lineage summary: Derived from 1:250 000 scale geological maps Scale: 1:250 000 Resolution: 250 Cell size: Positional accuracy: ± 250 m Attribute accuracy: Data is accurate at time of map compilation to the best knowledge of the people compiling the map, given the state of geological knowledge. Logical consistency: Data identified from field mapping and aerial photography interpretation at 1:250 000 scale. Completeness: As above Additional information: Attribute list: see attached listing
Metadata contact information	Metadata date: 11 July 1996 Metadata contact person: Roger Buckley Metadata contact organisation: DNRE, MPV Metadata contact email: roger.buckleyr@nre.vic.gov.au
Attribute list	Unit: The abbreviated formal rock unit id. code (e.g. Emv) Unit no.: Used only for granitoid plutons. The number quoted is that defined by White <i>et al.</i>, Petrology of Igneous Rocks. In JG Douglas & JA Ferguson, (eds) <i>Geology of Victoria</i>. Geological Society of Australia, Victoria Division. Melbourne, pp. 427–451. Name: The formal name for the rock unit/formation/member. Description & Description 1: A brief description of the unit.

AUSTRALIA: Mineral Occurrence Database (MINLOC)

Organisation	Australian Geological Survey Organisation (AGSO)
Abstract	Compilation of data for the MINLOC database began in 1989 and now contains information on about 50 000 mineral occurrences and deposits. Information for each location includes location co-ordinates, name of occurrence, and commodity(ies) of economic interest. The information in the database covers about 94 per cent of the Australian continent.
Contents	Citation Information Dataset Description Spatial Domain Contact Information Dataset Currency and Status Dataset Storage and Format Dataset Quality Metadata Contact Information
Citation information	<i>Data set title:</i> Mineral occurrence database (MINLOC) <i>Data set short title:</i> MINLOC <i>Jurisdiction:</i> Australia <i>Custodian:</i> AGSO <i>Publication date:</i> <i>Acknowledgments:</i> AGSO <i>References:</i>
Dataset description	<i>Abstract:</i> Compilation of data for the MINLOC database began in 1989 and now contains information on about 73 000 mineral occurrences and deposits. Information for each location includes location co-ordinates, name of occurrence, and commodity(ies) of economic interest. The information in the database covers about 94 per cent of the Australian continent. <i>Search words:</i> MINERALS Mineral Deposits, MINERALS Mine Sites <i>Location description:</i> Australia
Spatial domain	<i>North bounding coordinate:</i> -9.5 <i>East bounding coordinate:</i> 112.5 <i>South bounding coordinate:</i> -44.0 <i>West bounding coordinate:</i> 154.0 <i>Bounding polygon:</i> <i>Attribute list:</i> Mineral occurrence/deposit location name; location co-ordinates; mineral commodity(ies) present

Contact information	Contact organisation: AGSO Contact position: Geologist Contact person: Greg Ewers Contact address: AGSO City: Canberra State: ACT Contact phone: 02 6249 9580 Contact fax: 02 6249 9965 Contact email: greg.ewers@agso.gov.au
Dataset currency and status	Beginning date: 1989 Ending date: Progress: In Progress Maintenance and update frequency: 2–3 times per year
Dataset storage and format	Stored data format: Digital — Point Output data format: Hardcopy — Printed Map; Hardcopy — Other Native data format: Oracle — RDBMS (Relational Database) Access constraints: No Access Constraints
Dataset quality	Lineage summary: Each datapoint has reference to the source Scale: 1:250 000 Resolution: Cell size: Positional accuracy: 3 Grades of accuracy: 10 to 100 metres; 100 to 1000 metres; 1 to 10 kilometres. Attribute accuracy: Each data point is tagged with precision Logical consistency: Cross checking of datasets, Overlays of maps, User feedback Completeness: 94 per cent of Australia was covered on first pass basis Additional information:
Metadata contact information	Metadata date: 20 Jun 1996 Metadata contact person: Greg Ewers Metadata contact organisation: AGSO Metadata contact email: greg.ewers@agso.gov.au

VIC: Magnetics database

Organisation	Department of Natural Resources and Environment Minerals and Petroleum Victoria
Abstract	Magnetic data over Gippsland is mostly recent low altitude, close line spacing data flown by the Geological Survey of Victoria and the Australian Geological Survey Organisation. Several datasets were used, including the Orbost, Mount Wellington, Tallangatta, Orbost, Mount Wellington and Wangaratta datasets.

Contents	Citation Information Dataset Description Spatial Domain Contact Information Dataset Currency and Status Dataset Storage and Format Dataset Quality Metadata Contact Information
Citation information	<i>Data set title:</i> Gippsland region aeromagnetic data <i>Data set short title:</i> <i>Jurisdiction:</i> Victoria <i>Custodian:</i> Department of Natural Resources and Environment, Minerals and Petroleum Victoria <i>Publication date:</i> TALLANGATTA — 1995; WANGARATTA – 1997, ORBOST- 1994; MOUNT WELLINGTON – 1993. <i>Acknowledgments:</i> <i>References:</i>
Dataset description	<i>Abstract:</i> Magnetic data over Gippsland is a mosaic of several airborne surveys, mostly recent low altitude, close line spacing data flown by the Geological Survey of Victoria and the Australian Geological Survey Organisation. Several datasets were used, including the Tallangatta, Orbost, Mount Wellington and Wangaratta datasets. <i>Search words:</i> Minerals, Geophysics <i>Location description:</i> Gippsland, Victoria
Spatial domain	<i>North bounding coordinate:</i> -36.515 <i>East bounding coordinate:</i> 148.219 <i>South bounding coordinate:</i> -39.138 <i>West bounding coordinate:</i> 145.667 <i>Bounding polygon:</i> <i>Attribute list:</i>
Contact information	<i>Contact organisation:</i> Department of Natural Resources and Environment; Minerals and Petroleum Victoria <i>Contact position:</i> Manager Geophysics, Minerals and Petroleum Victoria <i>Contact person:</i> Alan Willocks <i>Contact address:</i> PO Box 500, East Melbourne, Vic 3002 <i>City:</i> Melbourne <i>State:</i> Victoria <i>Contact phone:</i> (03) 9412 5131 <i>Contact fax:</i> (03) 9412 5155 <i>Contact email:</i> alan.willocks@nre.vic.gov.au
Dataset currency and status	<i>Beginning date:</i> TALLANGATTA — 1995; WANGARATTA – 1997; ORBOST – 1994; MOUNT WELLINGTON — 1993 <i>Ending date:</i> As above <i>Progress:</i> All complete. <i>Maintenance and update frequency:</i>

Dataset storage and format	Stored data format: Digital — Database; Hardcopy — Maps, Reports Output data format: Digital — Mapinfo, ERMapper, TIFF, DS ASCII; Hardcopy — Plotted maps, Report, Transparencies Native data format: none Access constraints:
Dataset quality	Lineage summary: TALLANGATTA — Line spacing 200m, height 80m CORRYONG — Line spacing 200m, height 80m WANGARATTA — Line spacing 200m, height 80m ORBOST — Line spacing 200m, height 80m Scale: 1:250 000
Metadata contact information	Metadata date: 21 January 1997 Metadata contact person: Alan Willocks, Manager Geophysics Metadata contact organisation: Department of Natural Resources and Environment, Minerals and Petroleum Victoria. Metadata contact email: alan.willocks@nre.vic.gov.au

VIC: Mining tenements

Organisation	Department of Natural Resources and Environment Minerals and Petroleum Victoria
Abstract	The mining tenements database provides information and location of both current and expired exploration licences and mining licences in Victoria.
Contents	Citation Information Dataset Description Spatial Domain Contact Information Dataset Currency and Status Dataset Storage and Format Dataset Quality Metadata Contact Information
Citation information	Data set title: Victorian Mining and Exploration Tenements Data set short title: VICEL Jurisdiction: Victoria Custodian: Department of Natural Resources and Environment, Minerals and Petroleum Victoria Publication date: late December 1998 Acknowledgments: References:

Dataset description	Abstract: The VICEL data set is derived from the corporate GEDIS system, and as such represents a snapshot in time of continually changing data. The database provides an outline of current and expired Exploration Licences and Mining Licences together with information on dates held and licences. Search words: Minerals Mining and Exploration Leases Location description: Gippsland, Victoria
Spatial domain	North bounding coordinate: -36.515 East bounding coordinate: 148.219 South bounding coordinate: -39.138 West bounding coordinate: 145.667 Bounding polygon: Attribute list: see later
Contact information	Contact organisation: Department of Natural Resources and the Environment Contact position: Manager, Technical Applications Contact person: Andrew Wilson Contact address: PO Box 500, East Melbourne, Vic 3002 City: Melbourne State: Victoria Contact phone: 03 9412 5136 Contact fax: 03 9412 5151 Contact email: Andrew.Wilson@nre.vic.gov.au
Dataset currency and status	Beginning date: Nov 1996 Ending date: Progress: Complete Maintenance and update frequency: Daily (source dataset) Not planned (this dataset)
Dataset storage and format	Stored data format: Digital — Polygon, Digital-Database Output data format: Digital — Polygon, Digital — database, hard copy — maps; hard copy — reports Native data format: Distributed Via CD or disk or on-line for subscribers Access Constraints:
Dataset quality	Lineage summary: Sourced from accurate topographic maps Scale: 1:25 000 Resolution: 25 Cell size: Positional accuracy: + 25 metres Attribute accuracy: All information is accurate as far as MPV is concerned. Logical consistency: Completeness: Complete for State of Victoria Additional information:

Metadata contact information *Metadata date:* 21-January 1997
Metadata contact person: Andrew Wilson
Metadata contact organisation: Minerals and Petroleum Victoria
Metadata contact email: Andrew.Wilson@nre.vic.gov.au

Attribute list elcurr.

These files include the location and details of current Exploration titles (as at 21st November 1997).

Number	The Exploration Licence title number.
Type	The title type (EL for Exploration Licence, MP for an area excluded from title applications during the Moratorium period).
No. renewed	The number of times the title has been renewed.
Applicant	The name of the title applicant.
Priority	The title priority date.
Granted	Date the title was granted.
Expiry	Date the title is due for renewal/expiry.
Moratorium	Date the moratorium period expires.
Area	The area of the title in square kilometres.
Municipality	The municipal shire in which the title lies.
Status	The status for the title (CURRE for current, RENEW for under renewal, APPLI for under application).
DNRE	Region: The Department of Natural Resources and Environment region in which the title lies.

elhist

Title	The Exploration Licence title number
Applicant	The name of the title applicant.
Granted	Date the title was granted.
Expiry	Date the title is due for renewal/expiry.
Renewed	The number of times the title has been renewed.
Area sq km	The area of the title in square kilometres.
Municipality	The municipal shire in which the title lies.
Commodity target	The commodity target.
Expenditure	The amount of exploration expenditure reported to the Department. Exploration expenditure figures in square brackets ([]) indicate expenditure was jointly reported with several Exploration Licences not listed.
CONFID:	Appears where the details of the report are still confidential. Mapping, Ground geophysics, Air geophysics, Lit survey, Drilling Indicates if mapping, ground geophysical surveys, air-borne geophysical surveys, geochemical sampling surveys, literature surveys or drilling was recorded in the exploration activities.
Target (cont-cont2)	Brief description of the commodities and style of mineralisation sought.

mlcurr

This file contains data giving an image of the currently held Mining titles (as of 20 October 1995). Details of the titles can be viewed by opening the mlcurr.tab file (if not already opened), choosing the Info tool button in the Main Button Pad and clicking within the title you wish to inquire. The information displayed is:

Number	The Mining title number.
Type	The title type (DL for Development Lease, ESP for Extractive Search Permit, LIC for Extractive Industry Licence, LSE for Extractive Industry Lease, MAL for Mining Area Licence, MIN for Mining Licence, ML for Mining Lease, MRC for Miners Right Claim, and TRL for Tailings Removal Licence.
No. renewed	The number of times the title has been renewed.
Applicant	The name of the title applicant.
Priority	The title priority date.
Granted	Date the title was granted.
Expiry	Date the title is due for renewal/expiry.
Area	The area of the title in hectares.
Municipality	The municipal shire in which the title lies.
Status	The status of the title (CURRE for current, RENEW for under renewal, APPLI for under application).
NRE region	The Department of Natural Resources and Environment region in which the title lies.

Vic Mine Database

Organisation	Department of Natural Resources and Environment Minerals and Petroleum Victoria
Abstract	The VicMine database contains information on mines, prospects and mineral occurrences in Victoria.
Contents	Citation Information Dataset Description Spatial Domain Contact Information Dataset Currency and Status Dataset Storage and Format Dataset Quality Metadata Contact Information

Citation information	Data set title: VicMine Database Data set short title: VicMine Jurisdiction: Victoria Custodian: DNRE, MPV Publication date: Nov 1996 Acknowledgments: References: Weston, KS, 1992, Minerals Of Victoria 1:1 000 000 map report, Geological Survey Report 92.
Dataset description	Abstract: The VicMine database provides information on location, geology, production and resources of mines, prospects and mineral occurrences in Victoria. Search words: Minerals, Mineral Deposits Location description: Gippsland, Victoria
Spatial domain	North bounding coordinate: -36.515 East bounding coordinate: 148.219 South bounding coordinate: -39.138 West bounding coordinate: 145.667 Bounding polygon: Attribute list: See list below
Contact information	Contact organisation: Department of Natural Resources and Environment, Minerals and Petroleum Victoria Contact position: Manager, Mineral Resources Contact person: Roger Buckley Contact address: PO Box 500, East Melbourne, Vic 3002 City: Melbourne State: Victoria Contact phone: 03 9412 5025 Contact fax: 03 9412 5155 Contact email: roger.buckley@nre.vic.gov.au
Dataset currency and status	Beginning date: 1990 Ending date: 1999 Progress: In progress Maintenance and update frequency: Irregular
Dataset storage and format	Stored data format: Digital — DXF Output data format: Digital — ASCII, Digital-DXF, Digital-MapInfo; Hardcopy — report Native data format: Digital — Point Access constraints:

Dataset quality	Lineage summary: Data derived from literature with minor field checks. Scale: 1:25 000 to 1:1 000 000 Resolution: 25 to 1000 metres Cell size: Positional accuracy: Varies according to source, + 1 km to + 25 m. Attribute accuracy: As derived from literature review and geological appraisal from minor field checks. Logical consistency: Data compiled to best of ability given available resources. Completeness: Dependent on available data in literature. Additional information:
Metadata contact information	Metadata date: 21 January 1997 Metadata contact person: Roger Buckley Metadata contact organisation: Department of Natural Resources and Environment, Minerals and Petroleum Victoria Metadata contact email: roger.buckley@nre.vic.gov.au
Attribute list	NO Every mineral occurrence has a unique identifying number for each mine/prospect/mineral location. COMMODITY Gives the commodities produced, in abbreviated form. COMMODITY DESCRIPTION Describes in words the commodity code of the previous field COMMODITY GROUP Gives the field type of the commodity, e.g. Tin field, brown coal field, etc. FIRST COMMODITY Main commodity produced at that site. FIRST COMMODITY DESCRIPTION Explanation in words of the commodity code of the previous field.

FIRST COMMODITY TYPE
MET, FUEL or IND

FIRST COMMODITY TYPE DESCRIPTION
Explanation in words of the commodity type code of the previous field.

RESOURCE CLASS
MAJ, MIN or OCC

RESOURCE CLASS DESCRIPTION
Explanation in words of the resource class code of the previous field.

MAPSHEET NO
Standard 1:100 000 map sheet number.

ZONE
AMG zone 54 or 55

LOCATIONAL ACCURACY
1, 2 or 3

LOCATIONAL ACCURACY DESCRIPTION
Explanation in words of the location accuracy code of the previous field.

GEDIS REFERENCE NO
Minerals & Petroleum Victoria corporate reference database number.

GOLD PRIMARY PRODUCTION KG
Hard rock (primary) gold production from the site, as cited in references, primarily Bowen and Whiting 1976. 0 indicates unknown production.

GOLD ALLUVIAL PRODUCTION KG
Alluvial gold production from the site, as cited in references, primarily Bowen and Whiting 1976. Would generally be significantly understated from actual due to lack of official records. 0 indicates unknown production.

GOLD TOTAL PRODUCTION KG
Sum of primary and alluvial gold production from the site. 0 indicates unknown production.

**Contact
information**

Contact organisation: Department of Natural Resources and Environment, Minerals and Petroleum Victoria
Contact position: Manager, Mineral Resources
Contact person: Roger Buckley
Contact address: PO Box 500, East Melbourne, Vic 3002
City: Melbourne
State: Victoria
Contact phone: 03 9412 5025
Contact fax: 03 9412 5155
Contact email: roger.buckley@nre.vic.gov.au

VIC: Mineral Potential Tracts (21 maps)

Organisation	Australian Geological Survey Organisation (AGSO)
Abstract	Mineral Potential Tracts are assessed for their mineral potential based on 1:250 000 geological, geophysical and mineral occurrence datasets of the Gippsland region.
Contents	Citation Information Dataset Description Spatial Domain Contact Information Dataset Currency and Status Dataset Storage and Format Dataset Quality Metadata Contact Information
Citation information	<i>Data set title:</i> Mineral Potential Tract Maps <i>Data set short title:</i> Mineral Potential Tract Maps <i>Jurisdiction:</i> Victoria <i>Custodian:</i> AGSO <i>Publication date:</i> February, 1999 <i>Acknowledgments:</i> <i>References:</i>
Dataset description	<i>Abstract:</i> Mineral Potential Tracts are based on the Bairnsdale, Sale, Tallangatta, Wangaratta, Warburton, Warragul 1:250 000 geological maps. The tracts were created in ArcInfo/ArcView, and ArcView-Spatial Analyst by the Mineral Resources and Energy Branch, AGSO. Delineation of tracts and the assessment of mineral potential is based on a methodology adapted from that used by the United States Geological Survey. For description of methodology see the report. Database of Metallic Mineral Occurrences and information on the granite chemistry are used to delineate tracts. Description of deposit models, assessment criteria and brief description of tracts are included in the main report. Twenty-one maps represent the potential of twenty-one deposit types. These maps are fundamental in assessing mineral potential of the Gippsland RFA region. <i>Search words:</i> Mineral potential <i>Location description:</i> Gippsland, Victoria
Spatial domain	<i>North bounding coordinate:</i> -36.515 <i>East bounding coordinate:</i> 148.219 <i>South bounding coordinate:</i> -39.138 <i>West bounding coordinate:</i> 145.667 <i>Bounding polygon:</i> <i>Attribute list:</i> See attached listing

Contact information	Contact organisation: AGSO Contact position: Senior Research Scientist Contact person: Subhash Jaireth Contact address: GPO Box 378, Canberra City, ACT, 2601 City: Canberra State: ACT Contact phone: 02 6249 9419 Contact fax: 02 6249 9917 Contact email: Subhash.Jaireth@agso.gov.au
Dataset currency and status	Beginning date: 1998 Ending date: 1999 Progress: Complete Maintenance and update frequency: Irregular
Dataset storage and format	Stored data format: Digital – ArcInfo; Digital – ArcView3a Output data format: Digital – ArcInfo; Digital – shapefiles in ArcView3a; Hardcopy — report Native data format: ArcInfo/ArcView Access constraints:
Dataset quality	Lineage summary: Derived from 1:250 000 scale geological maps, geophysical, geochemical, mineral occurrence and other datasets of the Gippsland region. Scale: 1:250 000 Resolution: Cell size: 250mx250m Positional accuracy: See metadata sheet for Geology Attribute accuracy: 250mx250m Logical consistency: See metadata sheet for Geology Completeness: Complete as per assessments in February 1999 Additional information:
Metadata contact information	Metadata date: January 1999 Metadata contact person: Subhash Jaireth Metadata contact organisation: AGSO Metadata contact email: Subhash.Jaireth@agso.gov.au
Attribute list	‘Tract name_pot – expressed in numerical symbols (low =1, low to moderate=2, moderate=6, moderate to high=12, high=18, unknown=0). Certainty – levels of increasing certainty from A to D (for details see technical report)

Vic Composite Mineral Potential

Organisation	Australian Geological Survey Organisation (AGSO)
Abstract	Composite mineral potential shows the highest level of mineral potential of an area.

Contents	Citation Information Dataset Description Spatial Domain Contact Information Dataset Currency and Status Dataset Storage and Format Dataset Quality Metadata Contact Information
Citation information	<i>Data set title:</i> Composite mineral potential <i>Data set short title:</i> Composite mineral potential <i>Jurisdiction:</i> Victoria <i>Custodian:</i> AGSO <i>Publication date:</i> February 1999 <i>Acknowledgments:</i> <i>References:</i>
Dataset description	<i>Abstract:</i> Composite Mineral Potential Map/Dataset is a collation of mineral potential tracts of nineteen deposit types. The map was created by using Spatial Analyst Extension of ArcView3a. It represents the highest level of mineral potential assessed (in February 1999) for an area in the Gippsland region <i>Search words:</i> Composite mineral potential <i>Location description:</i> Gippsland, Victoria
Spatial domain	<i>North bounding coordinate:</i> -36.515 <i>East bounding coordinate:</i> 148.219 <i>South bounding coordinate:</i> -39.138 <i>West bounding coordinate:</i> 145.667 <i>Bounding polygon:</i> <i>Attribute list:</i> See list below
Contact information	<i>Contact organisation:</i> AGSO <i>Contact position:</i> Senior Research Scientist <i>Contact person:</i> Subhash Jaireth <i>Contact address:</i> GPO Box 378, Canberra City, ACT, 2601 <i>City:</i> Canberra <i>State:</i> ACT <i>Contact phone:</i> 02 6249 9419 <i>Contact fax:</i> 02 6249 9917 <i>Contact email:</i> Subhash.Jaireth@agso.gov.au
Dataset currency and status	<i>Beginning date:</i> 1998 <i>Ending date:</i> 1999 <i>Progress:</i> Complete <i>Maintenance and update frequency:</i> Irregular
Dataset storage and format	<i>Stored data format:</i> Digital – ArcInfo; Digital – ArcView3a <i>Output data format:</i> Digital – ArcInfo; Digital – shapefiles in ArcView3a; Hardcopy — report <i>Native data format:</i> Digital — ArcInfo <i>Access constraints:</i>

Dataset quality	Lineage summary: The map is derived from individual tract maps for nineteen deposit types, which were delineated using 1:250 000 geological, geophysical and mineral occurrence datasets of the Gippsland region. Scale: 1:250 000 Resolution: Cell size: 250mx250m Positional accuracy: See metadata sheet for Geology. Attribute accuracy: 250mx250m Logical consistency: See metadata sheet for Geology. Completeness: Complete as per assessments in February 1999 Additional information:
Metadata contact information	Metadata date: January 1999 Metadata contact person: Subhash Jaireth Metadata contact organisation: AGSO Metadata contact email: Subhash.Jaireth@agso.gov.au
Attribute list	Important attributes are: bcomp – numerical code representing levels of mineral potential (low=1, low to moderate=2, moderate=6, moderate to high=12, high=18)

Vic Cumulative Mineral Potential

Organisation	Australian Geological Survey Organisation (AGSO)
Abstract	Cumulative mineral potential shows the diversity of levels of mineral potential for an area.
Contents	Citation Information Dataset Description Spatial Domain Contact Information Dataset Currency and Status Dataset Storage and Format Dataset Quality Metadata Contact Information
Citation information	Data set title: Cumulative mineral potential Data set short title: Cumulative mineral potential Jurisdiction: Victoria Custodian: AGSO Publication date: February 1999 Acknowledgments: References:

Dataset description	Abstract: Cumulative Mineral Potential Map/Dataset is a collation of mineral potential tracts of 21 deposit types. The map was created by using Spatial Analyst Extension of ArcView3a. It takes account of the diversity of mineral resource potential. Standard scores based on subjective ranking of levels of mineral potential for overlapping tracts are added to derive a cumulative score. Areas with high cumulative scores indicate potential for more than one deposit type. Search words: Cumulative mineral potential Location description: Gippsland, Victoria
Spatial domain	North bounding coordinate: -36.515 East bounding coordinate: 148.219 South bounding coordinate: -39.138 West bounding coordinate: 145.667 Bounding polygon: Attribute list: See list below
Contact information	Contact organisation: AGSO Contact position: Senior Research Scientist Contact person: Subhash Jaireth Contact address: GPO Box 378, Canberra City, 2601 City: Canberra State: ACT Contact phone: 02 6249 9419 Contact fax: 02 6249 9917 Contact email: Subhash.Jaireth@agso.gov.au
Dataset currency and status	Beginning date: 1997 Ending date: 1999 Progress: Complete Maintenance and update frequency: Irregular
Dataset storage and format	Stored data format: Digital – ArcInfo; Digital – ArcView3a Output data format: Digital – ArcInfo; Digital – shapefiles in ArcView3a; Hardcopy — report Native data format: Digital — ArcInfo Access constraints:
Dataset quality	Lineage summary: The map is derived from individual tract maps for nineteen deposit types, which were delineated using 1:250 000 geological, geophysical and mineral occurrence datasets of the Gippsland region. Scale: 1:250 000 Resolution: Cell size: 250mx250m Positional accuracy: See metadata sheet for Geology. Attribute accuracy: 250mx250m Logical consistency: See metadata sheet for Geology. Completeness: Complete as per assessments in February 1999 Additional information:

Metadata contact information	<i>Metadata date:</i> 7 July 1998 <i>Metadata contact person:</i> Subhash Jaireth <i>Metadata contact organisation:</i> AGSO <i>Metadata contact email:</i> Subhash.Jaireth@agso.gov.au
Attribute list	Important attributes are: bcumu – numbers represent cumulative mineral potential (for details see the Technical Report)

